ANNEX: 2.6

Report on
Addressing Post-Harvest Constraints of Small Millets in South Asia

(Part of Objective 3)

IDRC Project Number: 106506

Research Institutions

DHAN Foundation (DHAN), India
Tamil Nadu Agricultural University (TNAU), India
All India Coordinated Small Millets Improvement Project (AICSMIP), ICAR, India
Arthacharya Foundation (AF), Sri Lanka
Local Initiatives for Biodiversity Research and Development (LI-BIRD), Nepal
McGill University (McGill), Canada

Location of Study
India, Sri Lanka and Nepal

Report period:
March 2011 to August 2014

Part of
Revalorizing Small Millets in the Rainfed Regions of South Asia

Foreign Affairs, Trade and Development Canada
Affaires étrangères, Commerce et Développement Canada

IDRC | CRDI
International Development Research Centre
Centre de recherches pour le développement international

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Acronyms

AICSMIP	:	All India Coordinated Small Millets Improvement Project
CFTRI	:	Central Food Technology Research Institute
CIFSRF	:	Canadian International Food Security Research Fund
DFATD	:	Department of Foreign Affairs, Trade and Development
DHAN	:	Development of Humane Actions
FGD	:	Focus Group Discussion
IDRC	:	International Development and Research Centre
LI-BIRD	:	Local Initiatives for Biodiversity, Research and Development
McGill	:	McGill University
RESMISA	:	Revalorizing Small Millets in rainfed regions of South Asia
SMACs	:	Small millet and associated crops
TNAU	:	Tamil Nadu Agricultural University
WASSAN	:	Watershed Support Services and Activities Network

Report on
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1 Introduction

Small millets are one of the oldest foods known to humans and possibly the first cereal grain to be used for domestic purposes. Small millets are a group of cereal crops belonging to the grass family Graminae. The origin of millet is diverse with varieties coming from both Asia and Africa. Small millets have been main staples of the people of semi-arid tropics of Asia and Africa for centuries where other crops do not grow well. They have been cultivated since time immemorial. Essential similarities of these small millets are their resilience and ability to thrive in harsh environments. The origin and common names of small millets are as follows.

Table 1: Origins and common names of small millets

Crop	Common names	Origin
Setaria italica	Foxtail millet, Thenai, Italian millet, German millet, Hungarian millet, Siberian millet	Eastern Asia (China)
Panicum sumatrense	Little millet, Samai	Southeast Asia
Paspalum scrobiculatum	Kodo millet, Varagu	India
Panicum miliaceum	Proso millet, common millet, hog millet, broom-corn millet, Russian millet, brown corn, Panivaragu	Central and Eastern Asia
Echinochloa crusgalli and Echinochloa corona	Barnyard millet, sawa millet, Japanese barnyard millet, Kudhiraivali	Japan
Eleusine coracana	Finger millet, African millet, koracan, ragi, wimbi, bulo, telebun, Ragi	Uganda or neighbouring region

Sources: 1) FAO, 1995 2) Rai et al., 2006

Small millets need very little inputs for their sustenance. They require only 25% of the water consumed by crops such as sugar-cane and banana. They do not demand rich soils for their survival and growth and can even grow on skeletal soils that are less than 15 cm deep. They can grow well with the use of farmyard manures and household produced biofertilizers as nutrients. They can also be termed as pest free crops since they are not attacked by pests during their growth or storage. All these extraordinary qualities of the millet farming system make them the climate change compliant crops.

In spite of all these extraordinary qualities and capacities of small millets farming systems, the area under cultivation of small millets has been shrinking over the last five decades across South Asia. In India, the area under cultivation declined from 4.7 million ha to 0.9 million ha (Decline of 46 % in finger millet and 80 % for the other small millets) between 1961 and 2009, rapidly after the green revolution period (DHAN Foundation and WASSAN 2012). This decline in area has a direct bearing on the overall decline in the consumption of small millets. In India, the finger millet consumption, declined by 47 %, while other small millets declined by 83%. Similarly the area under finger millet cultivation has been decreased drastically from 37306 ha in 1953 to 4199 ha in 2010/11 in Sri Lanka.

A number of factors are responsible for the steep decline in the production and consumption of small millets. Reduction of area under cultivation is mainly due to low productivity, high labour intensity, the drudgery of agricultural operations, and lack of attractive farm gate prices. The shift in food consumption away from the small millets in the producing regions was triggered by easy availability of rice and wheat through public distribution system. Inadequate investment in product development and commercialization has also been constraining consumption. Consumption of small millets is further constrained by low social status of small millet foods, resistance to change in dietary habits, and lack of knowledge on the use of small millets in the daily diet. Even if there is awareness, consumption is restricted due to inadequate availability of millets in local markets and high prices. These crops are left out of mainstream agricultural development and there has been inadequate policy support for small millets when compared to crops like rice and wheat. This situation was reflected in low investments in research, production, promotion and marketing and has an overarching influence on the constraints mentioned above.

Figure-1: Harvest and post- harvest constraints of small millets

One of the important issues faced by the rural communities is drudgery related to harvesting, threshing and dehulling of the small millets (Figure-1). This is one of the most important reasons for the drastic decline in consumption of small millets other than finger millet in the producing regions (Pradhan, Nag, and Patil 2010). Further, poor grain quality of small millets in terms of presence of extraneous matter like mud particles, and infected and unfilled grains is a major issue for processors and the food industry as it drastically reduces the quality of ready-to-eat and ready-to-cook food products. Deterioration of grain quality is mainly due to lack of harvesting, threshing and dehulling technologies, and infrastructure in place, coinciding of rains with harvesting season and inherent issues like kodo millet poisoning. These issues need comprehensive context specific solutions.

Harvesting, threshing, pre-cleaning, grading, parboiling, and dehulling are the basic operations involved in conversion of small millet grain into rice. The harvesters and threshers are used at farm level. These machines are available for other crops and they need to be improvised for small millets.

Particularly whole plant threshers are to be developed for small millets for areas where whole plant is harvested, instead of panicles. Pre-cleaners viz., destoners, aspirators and graders are the machines that are usually utilized to clean grains. These machines are already available for the pre-cleaning of paddy. They can be utilized by fine tuning them to suit cleaning of millets. The machines that have to be skillfully developed are the dehuller and separator. Small millets are well protected in glume encasements, hence the conversion of the grain to rice and other forms are time consuming and laborious. Presently, available machines to process small millets at village level are less efficient in terms of head rice recovery and loss of nutrients due to high level of polishing. Machines suitable for processing small millet grains at the village level need to be developed urgently to revive small millets and address issues related to food and nutritional security. The Revalorising Small Millets in Rainfed Regions of South Asia (RESMISA) project undertook research to address these critical gaps related to harvest and post-harvest operations of small millets by fine tuning the harvester, thresher and dehullers to make them suitable for small millets and to improve their performance to address drudgery related issues. The main objectives of the research are:

1. Survey of post-harvest technologies and constraints faced by women farmers
2. Developing/refining a dehulling machine that is appropriate and functional in terms of meeting the requirements at the research site and dissemination of the same.
3. Developing and evaluating a low temperature parboiled/dry roasting technique to debran millets.
4. Modification of existing harvesting/ threshing machinery for small millets
5. Enhancing the hygienic conditions of roadside pushcart millet porridge enterprise
6. Identification of technologies to reduce seed blackening in finger millet
7. Identification of technologies to reduce kodo millet seed poisoning

The research was carried out by Tamil Nadu Agricultural University (TNAU), All India Coordinated Small Millets Improvement Project (AICSMIP) and DHAN Foundation in India, Arthacharya Foundation in Sri Lanka, LI-BIRD in Nepal and McGill University in Canada. The following sections share the materials and methods, research results and the conclusions related to the research activities.

2 Materials and Methods

2.1 Survey on post-harvest technologies and constraints faced by women

This was undertaken in all the project sites with the following objectives

- To study the existing post-harvest handling practices followed in small millets and their associated crops
- To identify the problems and constraints faced by the farmers, especially women, during various stages of post-harvest handling of focused crops
- To enlist the best indigenous practice/knowledge, if any, related to harvesting, threshing, processing and storage in a particular crop across the sites
- To identify the areas of research to address the issues of PHT of small millets and associated crops

2.1.1 Methodology and methods

A participatory methodology was followed with community at the center, to elicit information about post-harvest processes followed in the research locations. The following four methods were followed for the survey of post-harvest technologies and constraints faced by women

1. Key informant interview- Interview of well informed and experienced farmers was taken up in getting an in-depth understanding of various post-harvest technologies and the constraints faced by the community and for observing tools and structures involved. Key informants were selected across the villages to understand the variations across the villages in the site. Efforts were taken to ensure a fair share of women among the key informants. An interview schedule was prepared for this purpose and used across the sites.
2. Focus Group Discussion (FGD) - FGD was conducted for capturing the collective understanding of PHT and constraints faced by the community and to capture variations across the families. FGDs were conducted across the villages to understand the variations across the villages in the site. Separate FGDs were conducted for men and women for understanding the difference between the genders on perceptions of post-harvest processes followed. In Nepal, pair wise ranking was used separately with men group and women group to prioritize the issues related to post-harvest.
3. Interview of other stakeholders: Interview was conducted with other stakeholders like mill owners and product manufacturers in the local area based on availability, to understand their perspective on post-harvest processes.
4. Photo documentation

2.2 Development of improved dehuller prototype

The parameters considered are capacity per hour and power requirements to match the village level infrastructure, improvement in head rice recovery, reduction in breakage percentage and reduction in polishing, besides acceptance in consumers in the producing regions. After the prototype was developed in the lab, field testing was done at the sites. The detailed note on methods and materials adopted for centrifugal dehulling was given in Annex 1.

2.3 Parboiling to debran small millets

Parboiling studies were carried out for barnyard and kodo millets. The milled samples were analyzed for hulling efficiency, head rice recovery, degree of parboiling, hardness, colour, cooking time, water uptake and swelling index using standard procedures.

2.4. Modification of existing harvesting /threshing machinery for small millets

2.4.1 Harvester

AICSMIP screened commercially available reapers for harvesting of finger millet and the Shrachi Taro Reaper was field tested. DHAN and TNAU field tested two models of harvester in two sites. Acceptance by farmers of the efficiency of harvesting, straw quality, and time and the number of labour involved was considered to assess the performance.

2.4.2 Thresher

(i) India: The TNAU team tested two paddy harvesters – 'Walk-in type' and 'Riding type' – for finger millet at Anchetty. The DHAN team along with a private fabricator evaluated two models of thresher – 'Four walker multi-crop thresher' and 'Pulse thresher' – for suitability for threshing finger millet. DHAN field tested 'Four walker multi-crop thresher' model in two sites for finger millet and kodo millet.

(ii) Nepal: LI-BIRD has tested two models of manual finger millet threshers developed by NARC in 2012.

(iii) Sri Lanka: AF has field tested three panicle threshers in the project area for threshing and polishing of finger millet.

Acceptance by farmers of the efficiency of separation of grains from straw, straw quality and, time and the number of labour involved was considered to assess the performance.

2.5 Enhancing the hygienic conditions of roadside pushcart millet porridge enterprise

A study of hygienic conditions of pushcart millet porridge entrepreneurs was done and the microbial load of the porridge sold by them was assessed.

2.6 Identification of technologies to reduce seed blackening in finger millet

The blackening of finger millet grains in the field was probed by AICSMIP using samples from Chitradurga District, Karnataka.

2.7. Identification of technologies to reduce kodo millet seed poisoning

Samples of infected kodo millet grains were examined by AICSMIP for microorganisms.

3 Results and discussion

3.1Survey of post-harvest technologies and constraints faced by women farmers

This survey was completed for all the project sites by the South Asian team and a report is given in the Annex 2. It highlighted the existence of rich repertoires of women's indigenous knowledge and practices in project sites and the considerable scope for learning across the sites. The results of this survey revealed that there are many constraints faced by the community in the sites related to post-harvest operations. The identified constraints and leads for research are enlisted below.

3.1.1 Major constraints in post-harvest handling of SMAC

- Harvesting coinciding with heavy rains and lack of sunny days leading to problems like lodging, shattering of grains, blackening of grains and straw, increased duration of heaping before threshing resulting in deterioration of quality of grain and sometimes germination of seeds in the fields (due to continuous rains).

- Drying for two to three days is a pre-requisite for easy grain separation during threshing, but this may not be achieved due to weather conditions.
- Low air during the winnowing increases the labour requirement to as much as 3 times of the labour requirement when there is good air.
- Labour shortage as majority of farmers do harvesting simultaneously. In Bero and Semiliguda, India, harvesting coincides with the harvesting of paddy and hence it is prioritized over finger millet.
- The labour requirement for harvesting and threshing operations is high and given the increase in wages, harvesting is becoming a costly activity.
- In Nepal it is observed that trampling by women results in rashes in the feet and beating with stick results in swollen patches in the palm. Further winnowing results in itching and respiratory problems.
- Threshing on roads leads to grain damage and loss. Threshing and drying on a mud floor is less efficient than on the cement floor and access to cemented threshing yards is limited in the project sites.
- Small stones, dirt and other varieties of finger millet get mixed with the grains during threshing and drying operation, thereby leading to loss in quality.
- Rodent damage is a significant problem with some of the sites for small millets and insect pests are a major problem with the associated crops.
- Lack of adequate processing facility for all small millets except finger millet.
- Dehusking is a tedious and time consuming operation undertaken by the women and an important reason for reduction of consumption

3.1.2 Leads for research

1) Weather related issues like heavy rains and cloudy weather during harvest and threshing were observed in many of the sites. The research leads are:

    - Identification of varieties that has ability to perform under these conditions like early maturing variety and variety with non-lodging and less shattering characters and including the same in the participatory varietal selection in the sites can be helpful.
    - Research on the issue of blackening of finger millet grains due to continuous rains during harvest for understanding the pathogen involved and for finding ways to address this issue.
    - Research on the issue of kodo millet poisoning for understanding the pathogen involved and for finding ways to address this issue.

2) Labour requirement for harvest and post-harvest operations for finger millet seems to be relatively higher than other cereal crops when it is seen in the background of low productivity and low value. Given its value as a nutritious crop, labour efficient practices need to be evolved to address this issue. As observed by few partner research organizations appropriate thresher can be a valid research agenda. More exploration across the sites for the exchange of best practices that can increase labour efficiency can be another approach. Pursuing this research

agenda can have significant benefits for women, who bear the major burden of post-harvest handling activities.

3) Introduction of small scale aspirators and de-stoners to other sites as in Anchetty, India has the potential to improve the hygiene and thereby the quality small millet products. Further exploration in this direction is needed to understand the site requirements and need for such an adaptive research.

4) Any research agenda in PHT of finger millet need to be sensitive about the consequences related to gender aspects, as women are the key players in the post-harvest processes. As women share a major part of the labour requirement, efforts for introduction of technology that helps in easing their work without they losing control over their occupation can be tried.

5) Sharing of best practices related to storage across the sites can help in managing pest problem with associated crops

3.2. Developing/refining suitable dehulling machine for the research site and dissemination of the same

Developing a suitable dehulling machine can significantly reduce drudgery of women associated with dehulling of small millets (other than finger millet) and can induce consumption of small millets by the cultivators. Dehulling is the process of removing the outer husk from the grains. It is a vital process for obtaining rice and for further processing of grains. A dehulling assembly includes destining, grading, dehulling and separation of hulled and unhulled grains (Figure-2). Usually dehulling is done by attrition, abrasion or impact hullers. Most of the available hullers work on the principles of attrition or abrasion while impact hullers are rarely used.

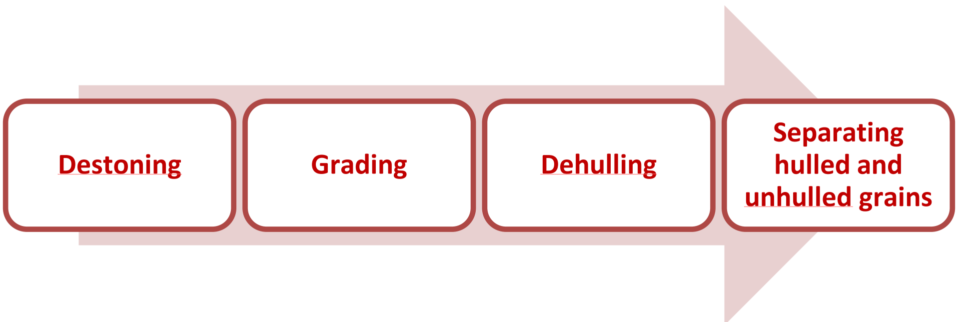


Figure-2: Dehulling assembly of small millets

In the project, the feasibility of adapting three different types of dehullers, namely rubber roller (compaction), attrition and centrifugal (impact) were investigated. While hulling with attrition or abrasive type hullers, the grains get polished and there is a considerable loss in nutrients due to the removal of the bran layer, whereas it is not so while using impact type dehullers, since there is no rubbing involved during the process. Following three research activities were taken to improvise and improve the existing dehuller models: 1) Improving the existing centrifugal dehuller prototype by TNAU with a capacity of more than 50 kg/ hour, 2) Developing rubber roller prototype of 100 kg/

hour capacity with the support of Central Food Technology Research Institute (CFTRI) and 3) Testing dehuller rubber roller prototype developed for household use by McGill under another CIFSRF project.

Dr Varadharaju, TNAU, tested the machines available to dehull the millets with kodo millet. It was found that, of all the technologies available for dehulling millets, centrifugal type dehullers along with pre-cleaning and grading mechanism are more efficient in dehulling. Dr. Varadharaju, TNAU took up trials to improve the existing model of centrifugal dehuller by changing speeds, the number of vanes, hitting surface, moisture content and number of passes. A prototype with 85 percent efficiency has been developed for little millet and was field tested in two sites. Based on the feedback from the community, few changes were made. The performance of these dehullers was found satisfactory by the local community. In case of kodo millet and barnyard millet the hulling efficiency was only 70-75 % with a breakage of around 10% even after four passes in the earlier prototype. In order to improve the efficiency of the huller and reduce the breakage, a double chamber de-huller was developed by TNAU team. The developed de-huller was evaluated for its performance with four millets namely little, foxtail, kodo and barnyard millet. The trials were carried out by changing the grain parameters (viz. type of millet, moisture content, parboiling) and machine parameters (number of impellers, type of casing, speed of the impeller, no of vanes, etc.) and the hulling efficiency and broken percentage were calculated. Maximum hulling efficiency of 88.50% and 89.25%, 82.50% and 81.50% was obtained in two passes for little and foxtail millet respectively, with a broken percentage range of 5 to 10%. The capacity of the de-huller is 75 kg/hr and is operated with 3 HP. Three phase motor. In the new prototype 5% and 7.5% increase in hulling efficiency was recorded over control in kodo millet and barnyard millet, and the head rice recovery, enhanced by 10% in the case of both millets over the range of experiments conducted.

The profile of the two centrifugal prototypes developed by TNAU is given below. The dehuller prototypes developed were widely disseminated through Doordharshan TV and other media.

Table 2 Specification for Single chamber millet dehuller

1.	Name of the machine	:	Single chamber millet dehuller
2.	Capacity	:	50 kg/hr
3.	Grains	:	Little millet, Foxtail millet, Proso millet
3.	Size of impeller(diameter)	:	12 cm x 5.3 cm 12 cm dia x 3.5 cm width(ID)
4.	Size of casing	:	22 cm x 5 cm (2 No's)
5.	RPM of motor	:	1420 rpm
6.	RPM of impeller	:	5000 rpm
7.	RPM of blower	:	1420 rpm
8.	Motor	:	2 HP single phase motor
9.	Blower type	:	Suitable blower
10.	Cost of dehulling	:	Rs. 2/kg

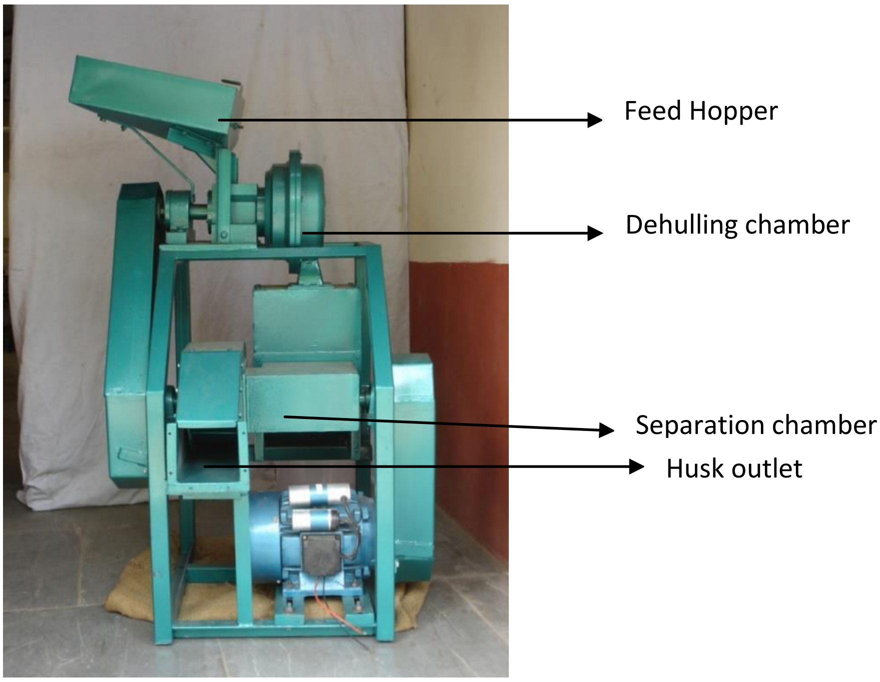


Figure-3: Single Chamber Centrifugal Dehuller for Millets

Table 3: Specification for Double Chamber Dehuller

1.	Machine Capacity	:	75 kg/hr
2.	Suitable for	:	Little, foxtail and proso millet, Kodo millet, barnyard millet
	TOP CHAMBER		
4.	Chamber Size	:	Ø 16 cm X 5 cm X 0.5 cm
5.	Chamber grain outlet	:	Ø 16 cm X 5 cm X 0.5 cm
6.	Impeller size	:	Ø 12 cm X 3.5 cm
7.	Number of vanes	:	3 vanes
	BOTTOM CHAMBER		
8.	Chamber Size	:	Ø 18 cm X 5 cm X 0.5 cm
9.	Chamber grain outlet	:	Ø 18 cm X 5 cm X 0.5 cm
10.	Impeller size	:	Ø 16 cm X 3.5 cm
11.	Number of vanes	:	3 vanes
12.	Blower	:	Suitable centrifugal blower
13.	Motor	:	3 hp three phase motor
14.	Size of the machine	:	80 cm X 120 cm X 150 cm
15.	Weight of the machine	:	200 kg
16.	Feed hopper	:	Suitable feed hopper for all grains
17.	Cost of the machine	:	Rs 75,000/-
18.	Cost of operation	:	Rs. 3/kg
19.	Additional fittings required	:	Housing block with roller bearing, Pillow block bearings, Transmission shafts with keyways, Grain outlet box, husk outlet box, pulleys, belts, screws, nuts and bolts

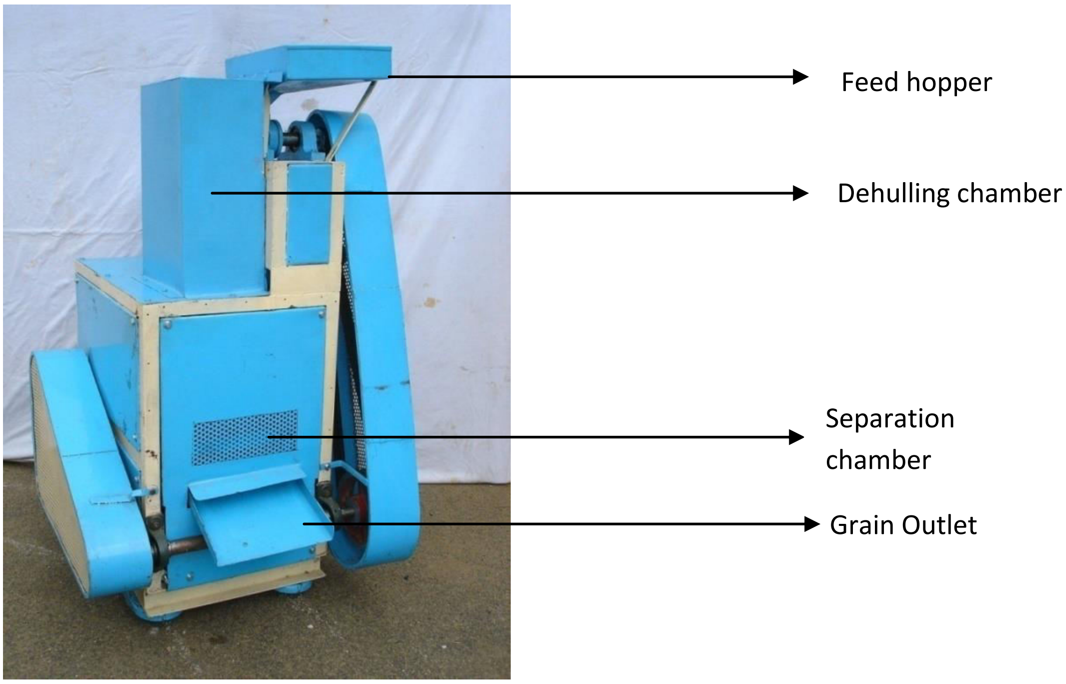


Figure-4: Double Chamber centrifugal Dehuller

CFTRI has earlier developed a lab model of rubber roller dehuller and as part of the RESMISA project has developed a 100 kg capacity rubber roller dehuller, which will be field tested. Dr. Raghavan and his colleagues at McGill, primarily supported by other CIFSRF project with UAS, Dharwad, have developed a dehuller for little millet for household-level. TNAU and DHAN teams visited Dharwad to assess the models. That prototype was field tested in two sites for little millet and barnyard millet, and found further modification is needed in the design. The millet mill from Central Institute of Agricultural Engineering was field tested in two sites. Design modifications were done by CIAE based on the field testing. In this process, working relationship was built with Victor Machines and AVM Engineering.

As mentioned earlier, one of the main constraints on the dehulling assembly is separating the hulled grains from dehulled grains. Under the project, CFTRI has developed a gravity separator prototype, which will be field tested. The profile of dehuller models field tested in the project is shared in the table-2 below.

Table 4: Profile of dehuller models field tested in RESMISA project

Sl. No.	Dehuller model	Designed by	Critical parameters
1.	Mini dehulling machine	Mc Gill and UAS-Dharwad	Rubber roller mill, 5 kg per hour capacity
2.	Improved centrifugal dehuller- prototype 1	TNAU	Impact type, single chamber, 40 kg per hour capacity
3.	Improved centrifugal dehuller- prototype 2	TNAU	Impact type, double chamber,75 kg per hour capacity
4.	Millet mill	Central Institute for Agricultural Engineering (CIAE), Bhopal	Abrasive type, 50 kg per hour capacity
5.	Rubber roller dehuller	CFTRI	Rubber roller type, 100 kg per hour capacity

3.3. Developing and evaluating a low temperature parboiled/dry roasting technique to debran millets

TNAU has optimized the parboiling process for kodo millet and barnyard millet. De-hulling of kodo millet and barnyard millet is a cumbersome process since husk and bran layers are bound tightly on the endosperm and their removal needs a special treatment. To ease the milling process, the millets were subjected to hydrothermal treatment at different levels of soaking temperature (60, 70, 80^{0}C), soaking time (6, 7, 8h), steaming periods (10, 15, 20 min.) shade dried and milled in a centrifugal de-huller. The milled samples were analyzed for hulling efficiency, head rice recovery, degree of parboiling, hardness, colour, cooking time, water uptake and swelling index using standard procedures. Hulling efficiency was recorded 5 % and 7.5 % increase over control in kodo millet and barnyard millet and the head rice recovery, enhanced by 10 % in the case of both millets over the range of experiments conducted. The increase in temperature of soaking, soaking time and steaming period increased the degree of parboiling, hardness (35.20 - 37.50 N in kodo millet and 27.50 to 28.50 for barnyard millet) and cooking time (10.50- 11.30 min.). Water uptake and swelling index decreased appreciably due to hydrothermal treatment. The treated samples were dark in color compared to raw grains and the change in L*, a*, b* values were highly significant.

Table 5: Experiment with Double Casing with grooves-Kodo millet (Parboiled)

Peripheral velocity m/s	No of vanes	No. of passes	Moisture content, %	Hulling efficiency, %	Broken, %
		2	10	**87.50**	7.25
35.05	3	2	12	85.50	6.25
		2	14	82.50	4.75
		2	10	85.65	4.50
32.50	3	2	12	83.25	3.40
		2	14	81.75	2.75
		2	10	**82.50**	**3.75**
30.00	3	2	12	80.75	3.25
		2	14	78.75	2.50

Table 6 : Experiment with Double Casing with grooves-Barnyard millet (Parboiled)

Peripheral velocity m/s	No of vanes	No. of passes	Moisture content, %	Hulling efficiency, %	Broken, %
		2	10	**86.50**	6.50
35.05	3	2	12	84.75	5.50
		2	14	82.55	4.50
		2	10	83.50	3.50
32.50	3	2	12	82.75	3.20
		2	14	81.50	2.75
		2	10	**78.50**	**2.75**
30.00	3	2	12	76.75	2.25
		2	14	74.50	1.85

3.4 Developing harvesting / threshing machinery for small millets

As identified in the post-harvest constraints survey, the farmers in the sites faced the issue of grain shattering and deterioration of quality of grains due to the coinciding of rainfall with harvesting time, besides labour scarcity and drudgery. Deterioration of grain quality like blackening in the case of finger millet leads to reduction in market price. Further threshing in mud floor and roads leads to mixing of extraneous matter in the grains, which are difficult to separate later and leads to a reduction in the quality of food products. The project attempted to improvise the existing harvesters and threshers to address these issues.

3.4.1 Harvester

The TNAU team tested two paddy harvesters – 'Walk-in type' and 'Riding type' – for finger millet at Anchetty. The efficiency of 'Walk-in type' harvester was more than 95 per cent. The performance was hindered by intercrops.

Figure-5: Types of harvester

Based on the results in Anchetty, 'riding type' of harvester was field tested for little millet at Jawadhu Hills, where it is grown as a sole crop. It was found satisfactory by the farmers. It was observed that the harvester performed well in leveled land free from stones and wetness with a standing crop of 2 feet and above. The main advantages observed were 1) Time saved, as the 'riding type' harvester completed harvesting of one acre in one and half hours when compared to the manual harvesting of 12 mandays per acre, 2) Ease in transport of bundles, as the harvested crop is bundled and arranged in a linear fashion, 3) No straw loss as straw cut height is equivalent to that of manual harvesting (unlike that of combined harvester where straw loss is observed) and 4) Suitable for harvesting small plots (unlike combined harvesters which can be used only in large plots). The farmers found it convenient to manage the labour scarcity in the site during harvesting, as all the fields almost matured at the same time and there is no agricultural labour class due to land ownership by all the families.

Figure-6: Field testing of Riding Type in little millet field in Jawadhu Hills

AICSMIP screened commercially available reapers for harvesting of finger millet and the Shrachi Taro Reaper was field tested (Ashoka *et. al.,* 2013).

Table 7: Comparison of mechanical harvesting and manual harvesting in finger millet

Sl. No.	Particulars	Unit	Manual	Mechanical (Reaper)	Difference
1	Area covered in unit time	m^2h^{-1}	83	2670	32
2	Labour efficiency	No. of labours ha^{-1}	16	0.5*	32
3	Cost of harvesting	Rs. ha^{-1}	2250	1140	1110
4	Loss of fodder	Kg ha^{-1}	220	540	320
5	Cost of fodder lost	Rs. ha^{-1}	550	1350	800
6	**Height of stem cut from ground level	cm	6 (3.6 %)	10 (9.1 %)	-

* Represents one labour for 4 hr (Half day)

**Considered average plant height of GPU-28 is 110 cm for calculations

(i) Time efficiency: One skilled person can operate the harvester. The machine can complete the harvesting of 1 hectare area in 4 hr (2670 m2hr-1). Whereas, manually a person in a day of 8 hr can complete only 660 m2 area (83 m2hr-1person-1). These results indicate that, the machine harvesting is 32 times more efficient in terms of time. In other words, by machine harvesting, a large area can be covered in a short period, which may enable in reducing the shattering and post maturity losses by harvesting at proper maturity.

(ii) Labour efficiency: In the present day of labour scarcity, use of mechanical harvester can save 32 labours for harvesting of one hectare area which indicates the dependency on labour can be reduced. Further mechanical harvesting places the harvested produce systematically so as to bundle the produce easily (Figure-7).

Figure-7: Proper placement of produce after harvest before bundling

(iii) Cost of harvesting: Manual cost of harvesting is Rs. 2250/ha as against Rs. 1140/ha mechanically, results in savings of Rs. 1110/ha.

(iv) Fodder loss: It is very difficult to cut the straw to the ground level (soil surface). Both manual and mechanical harvesting cuts the straw at a certain height of 6 cm and 10 cm respectively (Figure-6). This leads to loss of fodder to the extent of 220 Kgha-1 (6.2 %) and 540 Kgha-1 (9.1 %) respectively, as the average plant height of GPU 28 is 110 cm. This loss leads to an extent of Rs. 800.00 per hectare by reaper compared to the manual. However, mechanical harvesting reduces the labour cost and results in overall savings of Rs. 310.00 per hectare, in addition to the supply of organic matter to soil.

Figure-8: Comparison of height of stem cut from the ground surface

Therefore, the mechanical harvesting is highly advantageous over manual harvesting in the crisis of labour scarcity with large area of harvest in a less time in addition to organic matter supply to the soil.

3.4.2 Thresher

(i) India: While the existing multi crop threshers are suitable for threshing panicles of small millets as well with few modifications, they do not perform well in the case of whole plant threshing of small millets. This is particularly the case with finger millet, which is an important source of fodder for the site families. Finger millet straw hardens over time and the conventional threshing method of rolling a heavy stone helps in crushing the straw, which brings the inner juice outside by squeezing and makes the straw more palatable to the cattle. The DHAN team along with a private fabricator evaluated two models of thresher – 'Four walker multi-crop thresher' and 'Pulse thresher' – for suitability for threshing finger millet as whole plants. Initial trials showed that 'Four walker' model was suitable for threshing finger millet without wastage of straw. DHAN team continued evaluation of 'Four walker multi-crop thresher' model in two sites for finger millet and kodo millet and found it suitable for finger millet.

(ii)Nepal: In the RESMISA project sites, threshing and dehulling also require substantive labour. Usually, women are involved in these post-harvest operations. They usually trample the heads with their feet or beat the heads with stick to thresh the grains, which takes a substantial amount of time and thus increases their drudgery. In this context, LI-BIRD explored the availability of threshers for finger millet in the country. Nepal Agricultural Engineering Division of NARC (AED/NARC) is basically responsible to develop machineries. In 2012, finger millet thresher cum de-huller machines developed by NARC was tested in all the three sites of the project. The machine weighs about 60 kg. Despite some weaknesses in the machines farmers' groups demanded the threshers in 2013. Two of the farmers' groups shared 15% of the cost of the threshers. A separate study showed that 83 percent respondents (94.7% women) among 41 respondents found pedal threshers to be an important alternative for manual threshing. Feedbacks on the efficiency of the threshing machine were collected in 2014. The farmers preferred machine, but they also provided very critical feedback on the machine. There were both positive as well as negative responses on the thresher machines. Most of the farmers said that the farmers would benefit more if the thresher could be run by electricity. The key feedbacks on the threshing machine are as follows:

1. The machine is heavy to take it from one house to the other

- The feeder is very small and thus efficiency appears to be checked due to the small size of the feeder
- The pedal thresher needs at least two people to run the machine. To avoid this, it should be run by electricity

These feedbacks were shared in the RESMISA Sharing workshop (policy workshop) on 15 August 2014.

(iii) Sri Lanka: Threshing and polishing of finger millet was the serious drawback for the majority of farm women. Three threshing machines were field tested in three villages in the project site. These machines were found satisfactory for the farmers. The time taken for threshing and polishing was reduced by 35 per cent. AF also supported one woman farmer to set up a flour grinding mill in the site which has been serving as a milling centre and flour shop for the site community. Based on the experience gained from the project, AF trained the entrepreneurs supported by the Ufa Provincial Council, who had distributed grinding machines to start self-employment on grinding industry. The training program covered themes on improving the milling and proper packaging materials, and labeling, in order to make the new units compete with medium to large scale milling plants. Follow up information showed that the majority of millers have changed their practices, according to the instructions given. Video documentation field testing of thresher in the site was done and widely shared with the relevant audience, including policy makers and other NGOs (See http://www.dhan.org/smallmillets/av.php).

Figure-9: Field testing of finger millet thresher at Tanamalvila, Sri Lanka

3.5 Enhancing the hygienic conditions of roadside pushcart millet porridge enterprise

A survey was taken up in Coimbatore, India, to understand the practices of pushcart millet porridge vendors in terms of porridge preparation methods followed and hygienic practices adopted. Based on the study a training was conducted to the pushcart vendors to inculcate the principles of hygiene that determine the selection, location of their place of work; to understand the different methods of sanitizing and maintaining the utensils; to know the rules of hygiene to ensure food safety to the consumers. The follow up survey data revealed that 73% of the vendors started practicing personal hygienic practices like wearing gloves and aprons, covering their head, using disposable cups for serving and kept the porridge bowls covered with clean plates. The preparation of the porridge was also followed in a hygienic way. The microbial load of the porridge samples sold by the vendors was assessed and was found to be well within the safe limit.

Table 8: Total microbial Load of Millet porridge in Serial dilution of 10-6 (Bacterial count)

SAMPLES COLLECTED AREA	0 hr	After 3 hrs	After 6 hrs	After 9 hrs	After 12 hrs
Pearl millet porridge					
A	3.3	4.3	4.7	6.5	7.9
B	4.6	5.2	6.2	6.7	7.1
C	4.1	5.0	5.3	7.2	8.4
D	4.4	4.7	5.1	7.9	9.3
Finger millet porridge					
AA	3.4	5.0	5.4	6.7	7.9
BB	4.4	4.9	5.3	7.2	8.4

A, B, C, D – Pearl Millet Porridge; AA, BB – Finger Millet Porridge

A container for storing and hygienic handling of side dishes in the push carts on the roadside was developed. The container of the size 20 X 20 X 15 cm was fabricated, the container is cubical in shape and it has a transparent glass attached at the front side and the back plate is sloped downwards for easy movement of the dishes downwards towards the outlet. The side dishes are fed into the container from the top and it is closed with a lid. The dish items in the container slopes down into a curved collector from where it can be taken out by the customer. By this way, mass spoilage of the dishes due to mishandling can be avoided and also it can be protected from the environment. Multiple containers should be used for different dishes.

Figure-10: Women entrepreneurs selling millet based products (Before training)

Figure-11: Women entrepreneurs selling millet based products (After training)

3.6 Identification of technologies to reduce seed blackening in finger millet

After the crop harvest during kharif season, 2012, grain samples (70 farmers, constituting 9 villages) have been collected from the farmer's field in finger millet growing areas of three taluks of Chitradurga District in Karnataka. In each sample, 3000 grains were scored for normal, and complete blackening (Figure-10). The observations revealed that, seed blackening ranged from 0.50 to 20.9 percent with a mean of 5.3 percent. The frequency distribution of samples clearly indicated that, number of samples is equally distributed in the blackening range from 1 to 6 and more than 6 percent. Among three taluks, Holalkere taluk recorded higher seed blackening percent (8.2) compared to Chitradurga (4.8) and Hosakere (4.3). Individually higher values upto 20.9 percent are due to improper heaping practices. In overall, 5.0 percent seed blackening is recorded.

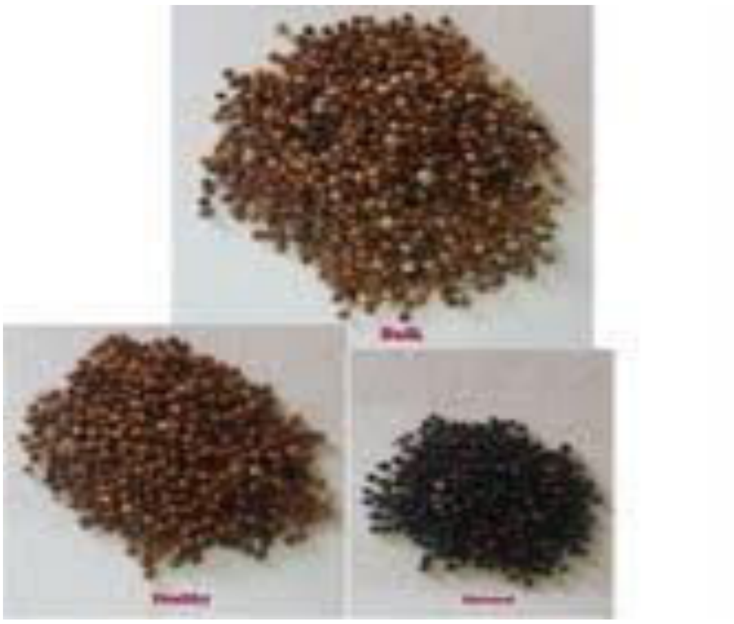


Figure-12: Comparison of normal and blackened seed

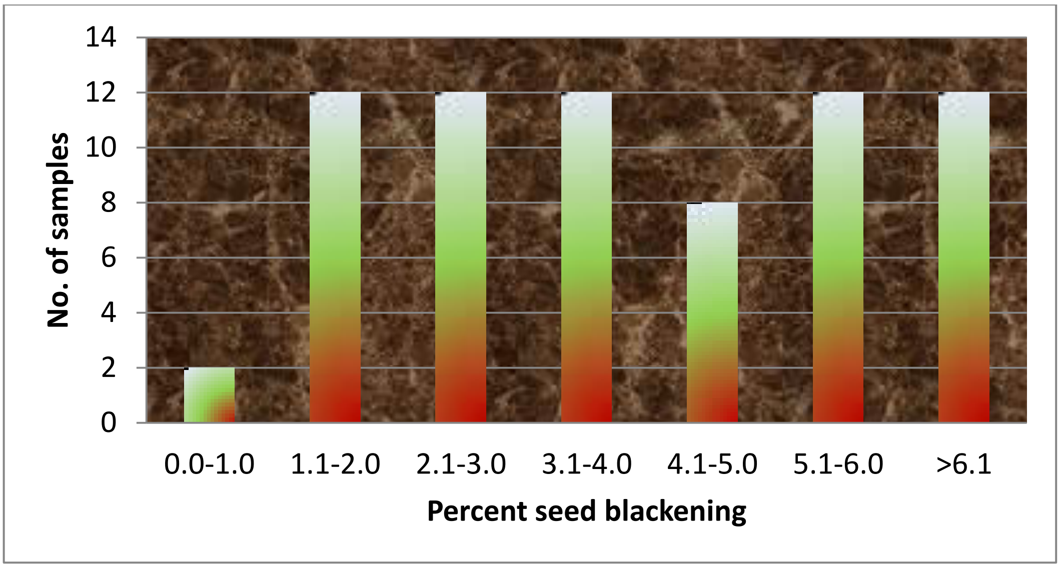


Fig. 13 Frequency distribution of grain samples for seed blackening in finger millet

3.7 Identification of technologies to reduce the kodo millet seed poisoning

Laboratory studies were conducted at the College of Agriculture, REWA, Madhya Pradesh during 2012-13. The kodo grain samples were collected from the experimental area and examined for the presence/absence of different microflora in the infected grain. The species associated with kodo poisoning were found to be Fusarium, Aspergillus, Curvularia and Sclerotium spp. However, the Fusarium spp. was found prominent.

In an another objective, the kodo grain samples collected from the farmers of seven districts of Madhya Pradesh during March to August, 2012 and showed no grain poisoning. However, the samples collected during September to January 2013 (Nine samples) reported kodo poisoning. Further, these samples were tested for toxin content at CFTRI Mysore. In Aspergillus, the cyclopiazonic acid (CPA, the toxin) content was measured and it ranged from 247 to 360 ug/ 100 g infected kodo grain. It is identified that most CPA is concentrated in husk fraction. Further, the CPA content can be reduced by processing methods viz., soaking, roasting, cooking or by preparations like roti or porridge compared to raw.

4 Summary and conclusion

Among the constraints that hindered consumption of small millets most important ones were drudgery related to post-harvest operations, mainly dehulling and reduction in quality of small millet products due to the addition of extraneous matter and deterioration of grain quality. Within this context of this objective, the project focused on the following major research areas:

1. Survey of post-harvest technologies and constraints faced by women farmers
2. Developing/refining a dehulling machine that is appropriate and functional in terms of meeting the requirements at the research site and dissemination of the same.
3. Developing and evaluating a low temperature parboiled/dry roasting technique to debran millets.

4. Modification of existing harvesting/ threshing machinery for small millets
5. Enhancing the hygienic conditions of roadside pushcart millet porridge enterprise
6. Identification of technologies to reduce seed blackening in finger millet
7. Identification of technologies to reduce kodo millet seed poisoning

4.1 Developing/refining dehuller for small millets

The project developed three prototypes. The single chamber centrifugal dehuller prototype developed for little and foxtail millet was field tested in two sites with 359 persons was found satisfactory by the local community. Then a double chamber de-huller was developed for kodo and barnyard millets, and another double chamber de-huller was developed and was evaluated for its performance with four millets namely little, foxtail, kodo and barnyard millet. The trials were carried out by changing the grain parameters (viz. type of millet, moisture content, parboiling), machine parameters (number of impellers, type of casing, speed of impeller, no of vanes, etc.) and the hulling efficiency and broken percentage were calculated. Maximum hulling efficiency of 88.50 per cent and 89.25 per cent, 82.50 per cent and 81.50 per cent was obtained in two passes for little and foxtail millet respectively, with a broken percentage range of 5 to 10 per cent. The capacity of the de-huller was 75 kg/hr and was operated with 3 HP three phase motor. The project has developed a rubber roller dehuller and gravity separator with a capacity of 100 kg/ hour with the support of Central Food Technology Research Institute (CFTRI) to develop dehuller assembly.

4.2 Modification of existing harvesting/ threshing machinery for small millets

In India, 'Four walker multi-crop thresher' and 'Pulse thresher' were evaluated for their suitability for threshing finger and kodo millets, and the first one was found suitable for finger millet. In Sri Lanka, a model of panicle thresher was introduced for threshing finger millet and found satisfactory for the farmers. In Nepal, two models of manual finger millet threshers developed by NARC were tested in 2012 and farmers opined that they will be effective if operated by electricity.
AICSMIP screened commercially available reapers for harvesting of finger millet and found the Shrachi Taro Reaper suitable based on field testing. DHAN and TNAU team tested two paddy harvesters – 'Walk-in type' and 'Riding type' – and found the former suitable for little millet sole crop in Jawadhu Hills.

4.3 Other research activities and results

1. Identification of organisms/ factors causing blackening of finger millet grains
2. Identification of organisms/ factors causing poisoning of kodo millet grains
3. The optimization of the parboiling process for kodo millet and foxtail millet
4. The microbial load of the porridge samples of street vendors was found to be well within the safe limit.

In summary, the three years of research in the project has resulted in three dehuller prototypes with increased efficiency, one gravity separator prototype, improvised threshers and harvesters in three countries and identification of ways to reduce blackening of finger millet grains and poisoning of kodo millet grains.

4.4 Research gaps

- Effective cleaner for removing the impurities having the same size and density as the grains.
- Small scale harvesters and thresher for different small millet cropping systems
- Small scale gravity separator for small millets for completing the machineries set for dehulling
- Low cost effective storage technologies for increasing shelf life of small millet products.

Way Forward

- Widely field testing the prototypes developed in the project and fine tuning them based on the client feedback.
- Taking up follow up studies to find solutions to address kodo millet poisoning.
- Popularizing the prototypes developed in the project with machinery fabricators and potential uptake agencies like millet focused project of the Government and other development agencies working with small millets.
- Scaling up of the relevant technologies across the provinces and countries through technology transfer and improvisation.
- Taking up client oriented research to address the research gaps mentioned above.

ANNEXES

Annex – 1: Methods and materials followed for centrifugal dehulling

Centrifugal dehulling is done by impact principle where a rotor and a stator are involved in attaining the desired result. The rotar imparts the required rotational speed to the grains, while the stator splits open the husk and brings out the grains due to the impingement. TNAU scientists have assessed two kinds of dealing machines, namely the abrasive emery mill type and the impact centrifugal type. Dr Vijaya Raghavan from McGill University provided input in this exercise. The TNAU team, along with Dr Vijaya Raghavan, developed a research plan to fabricate prototypes of dehulling machines for small millets, other than finger millet, that can reduce the drudgery of women in dehulling.

Development of a single chamber centrifugal dehuller

A prototype single chamber centrifugal dehuller was developed, tested and evaluated for its performance. The single chamber centrifugal dehuller consists of two main chambers namely a dehulling chamber and the separation chamber. In the dehulling chamber, opening out the husk and bringing out the grains takes place, while separation of grains and husk takes place in the separation chamber.

The centrifugal dehuller works on the principle of impact where the grains fed are rotated at high velocities within the impeller and thrown out to hit the casing. The husk is split open due to impingement of the high velocity grains on the casing. Grain and husk mixture comes out of the dehulling chamber. The mixture is taken to the separation chamber and they are separated by means of a blower. Unpolished clean grains are obtained from the grain outlet end and the husk is sucked by a blower and pushed out to husk outlet.

Components of a centrifugal dehuller

The developed centrifugal dehuller comprises of feed hopper, feed housing, impeller, casing, blower, separation chamber, discharge outlets for grain and husk and motor. The two main components of the centrifugal dehuller are rotating impeller and stationary casing. Proper designing of the impeller and configuration of the hitting surface decides upon the performance of the machine.

Flow chart for centrifugal dehulling

Feed hopper

↓

Hopper Housing

↓

Dehulling chamber (Splitting of grains takes place)

↓

Separation chamber (Blower separates grain and husk)

↓

Grains outlet | Husk outlet
↓ | ↓
Brown millet rice | Husk

Hopper: A feed hopper of the size 400 mm x400 mm x10 mm, that can hold 5 kg of the grains was fabricated and fitted to the machine. The feed rate of the grains was controlled by two major factors namely,

1) Slope of the feed hopper.
2) Size of the shutter opening.

The slope for different grains was varied by adjusting the base angle based on the angle of repose of the grains. The angle was adjusted by tilting the feed hopper with a screw adjustment provided at the bottom of the hopper. A square opening of the size 8cm x 8cm was provided at the bottom of the hopper. The feed rate of the grains was adjusted by varying the clearance size with a sliding gate. Smooth grain flow can be assured into the hulling chamber by astutely controlling both these factors. A conical channel pipe of the size 8 cm x 8 cm at the top and 5 cm x 5 cm at the bottom was attached to lead the grains into the housing.

Feed housing: The feed housing is the chief component bridging the feed hopper and the hulling chamber. A feed housing as given in the diagram was moulded with cast iron material (IS Designation – FG 400, Tensile strength – 400 Mpa and Brinell hardness number of 207-270 according to IS: 210 - 1993). The housing encloses a bearing on one side and holds the impeller on the other side. A 67.50 mm diameter core with a depth of 35 mm for attaching a double ball bearing was provided at the back end of the housing. On the other side, the impeller base is constructed like a telescopic pipe section. The same side acts as a wall for attaching the casing. A feed entry opening is provided at the top of the housing.

Grain entering the housing through the opening (75 mm x75 mm) provided at the top and falling into suction section (50 mm diameter circular section of 125 mm length) is continuously sucked by the rotating impeller. The movement of the grains is facilitated by the following factors given below.

a) The difference in pressure and distance between the feed point and eye of the impeller was created by the rotating impeller. The pressure below atmospheric pressure, i.e. pressure below 1.03 kgf/cm^2 was created by the rotating impeller. The suction pressure is maintained at a level so that grains reach the base plate of the impeller at very low velocities.
b) A box type opening at the top of the housing. At the top of the housing, an opening of 75 mm x 75 mm at the top and 40 mm x 40 mm at the bottom with a height of 50 mm was provided.

c) Sliding slope provided at the inner side of the suction chamber. Inclinations of 30º, 90º and 5º to the vertical plane at the receiving side, opposite side and other sides of the square were provided at the top of the impeller.
d) Size and surface texture of the suction chamber of the housing. The suction chamber is a cylindrical pipe section starting from the feed end and ending up into the eye of the impeller. It resembles a pipe of 50 mm diameter with a slope of 2º towards its exit. The surface should be smooth without any blow holes.
e) Clearance between the entry point and exit point of the housing. Clearances of 30, 40 and 50mm were provided for the study.
f) Slope of the tapered shaft that passes through the housing and gets connected to the impeller. A declining slope of 5º towards the impeller end.

Impeller: The impeller is the principal component of the dehuller where the velocities of the incoming grains are increased to a very high level. The high velocity grains impinge upon the casing surface leading to the splitting of the husk. A 120 mm x 40 mm impeller with three vanes and three different vane configurations were selected for the study.

The major components needed to fabricate an impeller are listed below,

a) Base plate
b) Crown plate
c) Vanes
d) Hub

Base plate: The base plate is a flat circular plate upon which the structure of the impeller is built. A well machined, 120 mm x 5 mm M.S. Plate, (IS: 1570 (Part-I)-1978 (Reaffirmed 1993))(Khurmi, 2012), was used as a base plate. A 20 mm bore was left at the center of the plate for fitting the shaft. The base plate, vanes and crown plate were assembled together as per the design requirements. The surface of the base should be rough enough to cause initial shearing of the grains. A hub of the size, (outer diameter - 40 mm, inner diameter - 20 mm, core diameter - 20 mm, length - 30 mm) was precisely fillet welded to the back of the base plate.

Vanes: Vanes guide the grains, entering the impeller, towards the outer periphery of the impeller. Meticulous design of the vanes ensures smooth flow of the grains within the impeller. A M.S. Plate of the required dimension was surface finished to obtain a smooth surface. A ring of the required thickness and curvature was cut from the plate. Grooves of 1 mm pitch and 2 mm depth was made on the inner side of the vane ring. Now, the vanes were cut into the required number of pieces. Three numbers of vanes were selected for the study as per the recommendation for handling semi-solids and solid materials by pump designers. Vanes with a radius of curvatures of 4 cm, 6 cm and 8 cm, thickness of 20 mm and width of 30 mm were fabricated for the studies. Three combinations of entry and exit angles, 10º and 30º, 20º and 30º and 30º and 30º were engineered for the studies (Ing. Bruno Eck, 1972). The edges of the entry and exit were cut to obtain the required inlet and exit angles. The inlet edge tip was sharpened to assure smooth flow of grains and to avoid any separation or whirling. The outer edge tip design of the vanes ensured proper exit of the grains from the impeller with high velocity to hit the surface of the casing.

Impeller one

3 VANE IMPELLER WITH GROOVES-Inner vane angle -30º, Exit angle - 30º

Crown plate and eye: The crown plate is the top plate used to cover the impeller. A M.S. plate of diameter 120 mm and thickness of 3 mm thickness was laser cut and surface finished. Then the core for eye of the impeller as per the size was cut. The inner surface of the crown plate was roughly finished for the shearing of the grains when they travel through the impeller. The base plate, vanes and the crown plate were properly aligned and while fitting the base plate, crown plate and the vanes.

The eye is an opening at the front of the impeller where grains enter the impeller. The size of the eye was cut exactly to fit as a continuity of the feed housing. This arrangement assures smooth entry of the grains without any spillage. The diameter of the eye opening should be at least half the diameter of the impeller for better pumping (William C. Osborne, 1977). The core size of this design is 60 mm assuring 50% of the total diameter as per recommendation.

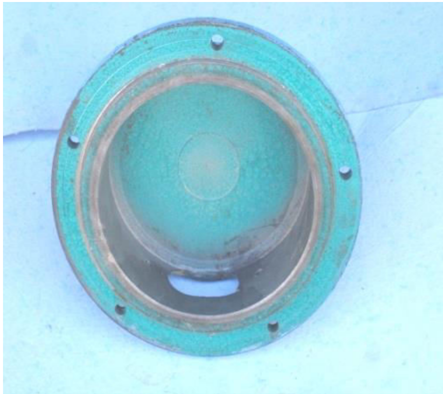
Hub: The hub is the portion of the impeller that is connected to the shaft. A central bore of 20 mm diameter was drilled out from a polished rod of 40 mm diameter and 30 mm length. The pipe made of M.S. plate was then fillet welded to the back of the base plate with high precision.

The whole impeller was mass balanced to add or remove material to or from the surface. Balancing was done to minimize vibrations, reduce wear and tear and avoid noisy operation.

Casing: Casing is the air tight enclosure that encloses impeller. The inner side of the casing acts as the hitting surface of the grains. The casing was made of cast iron as per the following standards, IS Designation – FG 400, Tensile strength – 400 Mpa and Brinell hardness number of 207-270 according to IS: 210 -1993. A casing of inner diameter 230 mm x 50 mm was fabricated for the study. The size was decided based on the volume of grains to be handled, weight of material consumed and ease of machining. The casing was moulded as two parts, i.e. the inner and outer casing. The inner part acts as the hitting surface of the grains coming out of the impeller at high velocity. The other half of the same diameter is attached to the inner casing is such a way that the inner horizontal plane of the whole is continuous without break with a slight taper towards the outlet placed at the bottom of the outer casing. The inner casing is attached to the feed housing.

Four types of hitting surfaces as given below were created for the study.

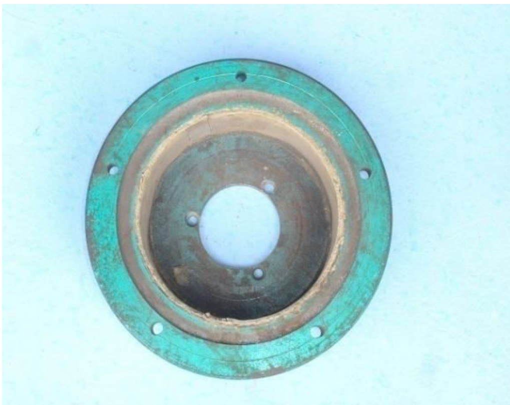
1) Casing with 1 mm grooved surface with 2 mm depth on the inner surface.
2) Flat surface with smooth finish.
3) Tapered surface with an angle of 60º to cause second hitting of the grains.
4) Tapered at an angle of 60º and grooved at a pitch of 1 mm and depth of 2 mm on the inner surface.



Outer Casing

Angular Casing

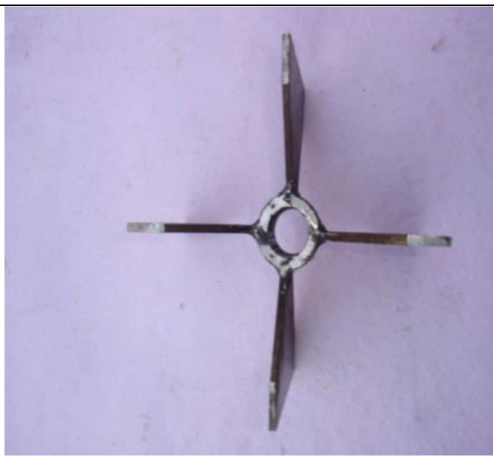
Grooved Casing



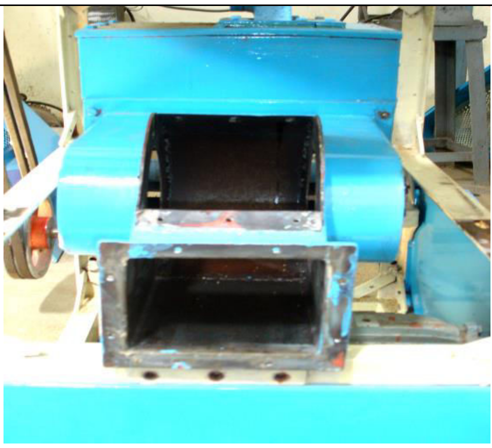
Casing with Rubber Lining

Separation chamber: The separation chamber of the size 300 mm x 300 mm x 400 mm is a box type structure fabricated with 12 gauge M.S. Sheet. The separation chamber is the portion where the grains and husk are separated by an aspirator connected at the back side of the chamber. Inside the chamber, six baffles made of mild steel sheet of the size 300 mm x 150 mm were welded to the front and back side of the box (three on the front side and three on the back side). The baffles were arranged alternately in a zig zag manner at an angle of 45º to the horizontal. This sort of arrangement slows down the grains and so effective separation takes place when it falls down from the last baffle into the suction chamber. An exposure area of 300 mm x 100 mm was allowed for complete suction of the grains. The husk and grains are separated by the aspirator and collected at two outlets provided separately.

Centrifugal blower: A centrifugal aspirator of the size ϕ250 mm was fabricated to remove the husk from the grains. A pipe of ϕ30 mm, length-100 mm and thickness-5 mm with a core diameter of 25 mm was turned to the required size using a lathe. Four numbers of the vanes were then welded to the outer surface of the base at 90º. A rectangular box of the size 200 mm x 100 mm running to a length of 200 mm was attached to the blower outlet. The blower was connected to the motor by a shaft of ϕ25 mm, 3 inch pulley and B-type v-belt.

FOUR VANE IMPELLER




SEPARATION CHAMBER

Husk outlet and grain outlet: The husk falling from the dehulling chamber is sucked and blown out through the grain outlet fitted at the rear side of the machine. The grain outlet, a rectangular box type chamber of the size 150 x 120 x 80 mm, is fitted to the outlet of the separation chamber. Good clean grains falling into the dehusking chamber are collected at the front side of the separation chamber. A sheet with an adjustable angle is connected to the front side of the chamber. The grains, falling into the chamber, slide out of the machine and get collected through the grain outlet.

Development of a double chamber centrifugal dehuller

A prototype double chamber centrifugal dehuller was developed, tested and evaluated for its performance. The centrifugal dehuller consists of two dehulling chambers and the separation chamber. While the design parameters followed are same as that of the single chamber dehuller, the main differences are mentioned below.

Dehulling using double chamber dehuller

Feed hopper

↓

Hopper Housing

↓

Dehulling chamber 1 (Splitting of grains takes place)

↓

Dehulling chamber 1 (Splitting of grains takes place)

↓

Separation chamber (blower separates grain and husk)

↓

Grains outlet → Brown millet rice

Husk outlet → Husk

Feed housing for second chamber: The grains coming out of the first dehulling chamber are sent into the second dehulling chamber. A feed housing as given in the figure was moulded with cast iron material (IS Designation – FG 400, Tensile strength – 400 Mpa and Brinell hardness number of 207-270 according to IS: 210 -1993). The housing encloses a bearing at one side and holds the impeller at the other side. A 67.50 mm diameter core with a depth of 35 mm for attaching a double ball bearing was provided at the back end of the housing. On the other side, the impeller base is constructed like a telescopic pipe section. The same side acts as a wall for attaching the casing. A feed entry opening is provided at the top of the housing.

Grain entering the housing through the opening (75 mm x75 mm) provided at the top and falling into suction section (50 mm diameter circular section of 125 mm length) is continuously sucked by the rotating impeller. The movement of the grains is facilitated by the following factors given below.

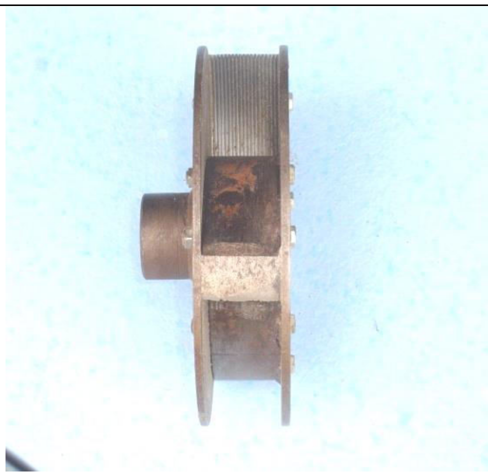
a) The difference in pressure and distance between the feed point and eye of the impeller was created by the rotating impeller. The pressure below atmospheric pressure, i.e. pressure below 1.03 kgf/cm^2 was created by the rotating impeller. The suction pressure is maintained at a level so that grains reach the base plate of the impeller at very low velocities.

Impeller for second chamber: The major components needed to fabricate an impeller are listed below:

a) Base plate
b) Crown plate
c) Vanes
d) Hub

Base plate: The base plate is a flat circular plate upon which the structure of the impeller is built. A well machined, 160 mm x 5 mm M.S. Plate, (IS: 1570 (Part-I) -1978 (Reaffirmed 1993)) (Khurmi, 2012), was used as a base plate.

Vanes: Vane with a radius of curvature of 8 cm, thickness of 20 mm and width of 30 mm were fabricated for the studies. Combinations of entry and exit angles of 30º and 30º were engineered for the studies (Ing. Bruno Eck, 1972).

	
3 VANE IMPELLER	**INLET VANE ANGLE - 30º** **EXIT VANE ANGLE - 30º**

Casing II: Casing with 1 mm grooved surface with 2 mm depth on the inner surface was selected based on the encouraging results obtained with the grooved casing in a single chamber machine.

OUTER CASING

GROOVED CASING

The grains fed into the feed hopper is regulated and uniformly fed by means of adjusting the clearance of grain passage. The grains pass into the housing and then into the dehulling chamber where it gains energy due to the rotational speed provided to them by the rotating impeller. From the impeller, the grains at high energy levels are made to impinge on the casing placed at a distance. The husk splits open due to the high impact energy of the grains on the casing. The husk and grain combination passes into the second chamber where the grains are subjected to impact once again and the remaining unhulled grains are hulled by impingement on the second casing. The grains along with the husk passes into the separation chamber where the husk is blown away by the blower and good grains are collected at the grain outlet.

Annex-2: Survey of Post-harvest Technology and Constraints Faced by Women related to Small millets and associated crops

1. Introduction

Among the major global issues, food and nutrition security, especially in developing and underdeveloped countries, are the biggest challenges of the present agricultural scenario. While the policy decisions to increase food production through modern agricultural movements like "green revolution" have been successful in some well endowed areas, they have not benefited those countries and regions which have the major area under rainfed agriculture. Analysis of the crisis reveals that modern agriculture laid over-emphasis on a few major crops like wheat, rice, maize, leading to a continuous decline in crop diversity on cultivated lands. Most of the crops like millets, pulses and oilseeds, which are grown largely under rainfed situations, were marginalized and efforts on research and development activities in rainfed farming were comparably insignificant. Several studies have indicated that the millets and their associated crops like pulses and oilseeds, which formed staple food grains of the farming community in the past, are highly nutritious and are most suited to semi-arid regions.

Realizing the significance of small millets to enhance the food and nutritional security of the people, a consortium of partners in India, Sri Lanka, Nepal and Canada is jointly working on an IDRC/CIDA funded initiative 'Revalorizing Small Millets in Rainfed Regions of South Asia' (RESMISA). The two major objectives of the project are a) To increase the area under production and productivity and b) To transform the increased production into increased consumption. For realizing the second objective, one of the major interventions envisaged in the project is to overcome the difficulties associated with post-harvest operations of small millets and their associated crops. Being marginalized crops in terms of scientific research and socio-cultural values, not much scientific investigation has taken place either to evaluate the traditional practices or to develop new methods to deal with the post-harvest problems, especially the processing of small millets. Further, it is important to understand the site specific situation and the needs of the community related to post-harvest. So this survey on post-harvest technology (PHT) and constraints faced by women farmers was undertaken in all the project sites as part of the project, with the following objectives:

- To study the existing post-harvest handling practices followed in small millets and their associated crops
- To identify the problems and constraints faced by the farmers, especially women, during various stages of post-harvest handling of focused crops
- To enlist the best indigenous practice/knowledge, if any, related to harvesting, threshing, processing and storage in a particular crop across the sites
- To identify the areas of research to address the issues of PHT of small millets and associated crops

2. Methodology and methods

A participatory methodology was followed with community at the center, to elicit information about post-harvest processes followed in the research locations. The following four methods were followed for the survey of post-harvest technologies and constraints faced by women:

1. Key informant interview- Interview of well informed and experienced farmers was taken up in getting an in-depth understanding of various post-harvest technologies and the constraints faced by the community and for observing tools and structures involved. Key informants were selected across the villages to understand the variations across the villages in the site. Efforts were taken to ensure a fair share of women among the key informants. An interview schedule was prepared for this purpose and used across the sites (See Annexure 2A)
2. Focus Group Discussion (FGD) - FGD was conducted for capturing the collective understanding on PHT and constraints faced by the community and to capture variations across the families. FGDs were conducted across the villages to understand the variations across the villages in the site. Separate FGDs were conducted for men and women for understanding the difference between the genders on perceptions of post-harvest processes followed. In Nepal pair wise ranking was used separately with men group and women group to prioritize the issues related to post-harvest.
3. Interview of other stakeholders: Interview was conducted with other stakeholders like mill owners and product manufacturers in the local area based on availability, to understand their perspective on post-harvest processes.
4. Photo documentation

2.1 Number of FGD and key informants

The number of villages, the number of FGD and a number of key informants for the household survey varied from site to site (Table 1). In Nepal, the key informants were identified during FGD, based on their years of experience in growing millets.

2.2 Data entry and analysis

After completion of FGDs and household level interviews, quantitative data obtained were compiled in Microsoft Excel sheet and analyzed.

2.3 Report preparation

While the individual site team collected data and prepared the site specific report for Nepal, Sri Lanka, Semiliguda, Bero and Dumriguda sites, Tamil Nadu Agricultural University did the study in collaboration with the DHAN Foundation in Anchetty, Jawadhu Hills and Peraiyur. The current report is prepared by DHAN Foundation by compiling the site specific reports, with the focus of comparative analysis of PHT and constraints faced by women related to small millets across the sites to get an overall picture and to link the findings of the survey with the research objectives and activities of the RESMISA project.

Table -1: Number of key informants and FGDs in different project sites

Country	Project sites	Number of villages	Number of key informants			No of FGDs
			Male	Women	Total	
Nepal	Dhikurpokhari VDC, Kaski district	3	2	2	4	1
	Kaskikot VDC, Kaski district		2	2	4	1
	Jogimara VDC, Dhading district		2	3	5	1
India	Peraiyur, Madurai district	10	24	26	50	5 Men groups + 5 Women groups
	Jawadhu Hills, Tiruvannamalai district	6	9	21	30	2 Men groups + 3 Women groups
	Anchetty, Krishnagiri district	6	17	13	30	3 Men groups + 2 Women groups
	Semiliguda, Koraput district	8	6	7	13	
	Dumriguda, Visakapatnam district	3	9	6	15	1 with mixed group
	Bero, Ranchi district	6	3	2	5	1 Men group and 1 Mixed group
Sri Lanka	Thanamalwila, Monaregala district	3	20	20	40	

3. Findings

The study was restricted to the important small millet crops and their associated crops (SMAC) in each project site. The focus crops identified at each project site are listed in Table 2. Finger millet is the focus crop in seven sites located in Nepal, India and Sri Lanka. Little millet is the main crop in Jawadhu Hills while it is also grown largely in Semiliguda and Dumriguda sites in addition to finger millet. Barnyard millet and Kodo millet are grown only at Peraiyur site. The results of the survey for each of the project sites were compiled cropwise and presented in the following sections.

Table -2: Focus crops in different sites

Sr. No.	Project sites	Small millet crops	Associated crops	Cropping pattern
1	Nepal			
	Dhikurpokhari VDC	Finger millet	--	As relay crop in maize
	Kaskikot VDC	Finger millet	--	As relay crop in maize
	Jogimara VDC	Finger millet	Horsegram, Rice bean	As relay crop in maize, sole crop
2	Peraiyur	Barnyard millet, Kodo millet	Field Bean	Sole and mixed crop
3	Jawadhu Hills	Little millet, Finger millet	Horsegram, Niger	Sole and mixed crop
4	Anchetty	Finger millet	Horsegram, Field bean	Sole and mixed crop
5	Semiliguda	Finger millet Little millet	Horsegram, Niger	Sole crop
6	Dumriguda	Finger millet Little millet	Horsegram, Niger	Sole crop
7	Bero	Finger millet	Horsegram, Linseed	Sole and mixed crop
8	Thanamalwila, Sri Lanka	Finger millet	Cowpea	Sole crop

3.1 Finger millet

Harvesting (includes harvesting, transporting, staking and drying)
The harvesting of finger millet crop takes place mainly during October to November in India and Nepal, while the cropping season for the crop is different in Sri Lanka (Table 3). There are two methods of harvesting followed across the sites.

1. Harvesting of only panicles - After crop maturity, the matured panicles (ear heads) are collected by cutting with the help of sickle leaving the plant stalks as such in the field; the operation is being carried out at one time or at intervals depending on the uniformity of maturity. The harvested panicles are gathered in a container, such as bamboo baskets (*Tokri)* at Bero, before heaping them in a convenient place. The panicles staked in heaps are left for sun drying for a period ranging from one week to more than a month. Some of the farmers believe that the heat generated within the heap will help in easy separation of grains while threshing. In Nepal, while this practice of softening of finger is there, it is observed that if this period of softening exceeds 15 days it results in deterioration of quality of grains. While at Bero site the panicles are displaced frequently within the heap using an iron raking tool with long wooden handle for better aeration, at Sri Lanka the panicles are spread on the floor for sun drying for two to three days and then stored in sacs before threshing.
In some sites like Thanamalwila, Sri Lanka, the uncut stalks are left in the field for grazing by the domestic animals and later the left out stables get incorporated into the soil during land preparation. In Nepal and Jawadhu Hills the stalks are collected by cutting them at the base and

stored for using as fodder, which means doing cutting operation twice, one for collecting panicles and another for stalks.

Table-3: Harvesting operation in finger millet at different project sites

Project sites	Time of harvesting	Harvesting methods	Transporting	Labor requirement /acre	
				Men	Women
Nepal site	Oct – Nov	Collecting ear-heads, staking in heap 1 week, cutting straw later	Ear-heads on head load	11	34
Anchetty	Oct – Nov	Straw with ear-heads, spreading in field for 2-4 days, staking for 1- 1 ½ months	Bundles of straw on head load	3	20-25
Semiliguda	Nov 2nd half	Straw with ear-heads, spreading in field for 10-12 days, staking upto 1 ½ months	Bundles of straw on head load	5	10
Dumriguda	Nov – Dec	Straw with ear-heads, spreading in field for 2-3 days, staking upto 1 month	Bundles of straw on head load	4-6	6-8
Bero	Oct 2nd half	Ear-heads collected in tokri, staking in heap for a few days to one month	Ear-heads on head load	1	26
Jawadhu Hills	Oct	Ear-heads alone harvested, 2 days drying, staking for up to one week	Ear- heads on head load	3	10
Thanamalwila	Jan	Ear-heads collected at intervals, spread on the floor, sun dried 2-3 days, stored in sacks	Ear-heads on head load	NA	NA

Note: NA- Not available

2. Harvesting of stalks along with panicles – This is the most commonly followed method in the areas of large scale cultivation of finger millet, say like Anchetty. The harvested stalks are spread in rows in the field for sun drying, commonly for two to four days and may go up to 12 days depending on weather conditions. The harvested stalks are bundled and staked near the threshing yard. In case of rainy days, farmers in Anchetty follow a staking practice called as *Sanai*, which involves arranging the bundles remaining in the field in closed lines in slanting position and covered with dried straw to prevent dampening. After 10-12 days the cover is removed and allowed to dry for one to two days before staking at the yard. Staking of bundled stalks is an art. It is usually done by arranging the bundled stalk in such a way that the panicles are covered inside the heap and rain water does not enter into the heap. So, such a staked heap is kept for a period of one to one and half months before threshing. A special type of wooden structure, called *Bhadi* is used for staking stalk bundles near threshing yard, in Semiliguda site. A wooden structure with four pillars and straw fixed above it is

prepared. They arrange the bundles of finger millet properly on the frame and cover it with straw so that it will not be damaged by animals and rainfall, this is called as *Bhadi.*
The labour requirement for harvesting operation varies across the project sites. Though both men and women are involved in harvesting operations, women labor who carry out most of the activities. Because of very different method of harvesting (harvesting panicles and stalk separately) followed in Nepal the labor requirement per unit area is comparatively high.

The major issues faced during harvesting and staking are

1. Harvesting coinciding with heavy rains and lack of sunny days leading to problems like lodging, shattering of grains, blackening of grains and straw, increased duration of heaping before threshing resulting in deterioration of quality of grain and sometimes germination of seeds in the fields (due to continuous rains). Last year Anchetty farmers were severely affected by blackening of grains and straw. The consumption quality of grains has deteriorated, lower price was realized and they could not use their own produce as seed in the next year. Farmers belonging to Bedrahalli, Anchetty observed that the variety *Sharadha* did not shatter the grains due to heavy rainfall while other varieties in vogue had significant loss due to shattering of grains. Bero farmers observed that the curved fingered varieties (*Demba* – an introduced short duration, high yielding variety) retained rain water in the heads and hence lodged, while the open fingered (*Gibra* – a traditional long duration variety) varieties did not retain water in the heads and hence did not lodge.
2. Labour shortage as majority of farmers do harvesting simultaneously. In Bero and Semiliguda, harvesting coincides with the harvesting of paddy and hence it is prioritized over finger millet.
3. Non synchronous maturing of the panicles, may be due to use of a mixture of different varieties (Nepal)
4. The labour requirement for harvesting operation is high and given the increase in wages, harvesting is becoming a costly activity.

Threshing (grain separation, winnowing, bagging and transport)
There is a lot of variation across the sites related to threshing operation, as seen from table no. 4. The study indicated that different types of threshing yard are used across the project sites. Leveled mud floor smeared with cow dung slurry, home courtyard, concrete yard, and public tar roads are commonly seen as the available threshing yards in finger millet growing sites.

Table-4: Threshing, winnowing, cleaning, drying and bagging of finger millet

Project sites	Threshing methods	Winnowing and cleaning	Drying and bagging	Labor requirement /acre	
				Men	**Women**
Nepal site	Hand pounding the panicles with stick in home court yard during day	Manually during windy hours: Bamboo equipments *nanglo* and *chalnu* used	Sun drying for 2-3 days	16	28
Anchetty	Use of stone roller (*kundu*) with a bullock pair in mud yard	Manually during windy hours, iron rakes and sieves for cleaning	Sun drying 1 day, nylon woven or gunny bags	12	12
Semiliguda	Trampling by bullocks, hand pounding partially threshed panicles with stick in mud yard	Manually during windy hours, cleaning with *chaluni*	Sun drying in home court yard		
Dumriguda	Using cattle and/or hand pounding with stick in mud yard	Manually during windy hours, lit up fire to generate wind flow	Sun drying in home court yard	4-8	5-12
Bero	Using bullocks or tractor and hand pounding in mud yard/ tar road	Manually during windy hours	Sun drying in home court yard 1-2 days	2	6
Jawadhu Hills	Beating with stick upto 1 bag and trampling by bullocks for more volume	Manually during windy hours, *visu muram* used for cleaning	Sun Drying for one day	4	6
Thanamalwila	Hand pounding using mortar and pestle	Manual using special device, cleaning with device made up of clay	Sun drying in home court yard 3-4 hours	Only wom en	

Separation of grains – Threshing methods for separating the grains from the panicles are also variable (Table 4) based on the scale of cultivation and availability of infrastructure. Spreading of panicles or stalk with panicles is done early in the morning and threshing starts from 10 o'clock. Threshing of only panicles or stalks with panicles, especially when the quantity is large, is usually done by using bullocks (4-5 in number) for trampling or by stone roller drawn by a pair of bullocks. The stone roller is known as K*undu* in Anchetty site and its size is about 2 ½ feet in length and 2 feet in diameter (see picture 1 below). On tar roads, the vehicular movement helps in separation of grains from the panicles. In place of bullocks tractor is also used by some farmers. In Nepal beating the heads with sticks in the home courtyard or trampling under feet by women is followed for threshing the panicles while mortar and pestle is used in Sri Lanka. Hand pounding is usually followed to thresh the small quantity of partially threshed panicles remained after cleaning the separated grains in other methods. It is observed in Anchetty that some farmers use paddy threshers for threshing finger millet, which need to be further explored for understanding its benefits to the farmers.

Picture 1: Stone roller (Kundu) for threshing finger millet in Anchetty

Winnowing and cleaning – Winnowing is done manually during windy hours, usually in the afternoon. Before winnowing the threshed bulk is cleaned from straw using iron rakes followed by first winnowing for cleaning from the straw pieces and dust. Sieves are used for cleaning straw pieces, stone particles and other materials, and this operation is handled by two men. The un-husked grains are hand pounded and mixed with the bulk produce before final winnowing. In Nepal winnowing is done using bamboo made local equipments (*Nanglo, Chalnu*) are used. The cleaned grains are usually sun dried for one to two days before bagging.

Picture 2: Winnowing **Picture 3: Threshing yard**

The threshing operation is completed in one day or it may get extended to the next day. Both men and women are involved equally in most of the sites, but in Nepal more women are required and it is only women who do the threshing operation in Sri Lanka. In Dumriguda site fire is lit to generate wind flow if there is not much natural wind flow. They also tie cloth to a tree to know the wind direction. In Bero farmers observed the *Gibra* variety was more easily threshed than the *Demba* variety.

In Sri Lankan site, since the drying of finger millet panicles is done on the floor of famer’s house, addition of sand is a serious problem. Once the seeds are removed, sand is separated using a special device made of clay in the presence of water. Once sand is separated grains are again sun dried two to three hours. Cloudy weather is a problem for this operation. These operations are done by women.

Issues

1. In Nepal it is observed that trampling by women results in rashes in the feet and beating with sticks results in swollen patches in the palm. Further winnowing results in itching and respiratory problems.
2. The labour requirement for threshing operation is high and given the increase in wages, threshing is becoming a costly activity.
3. Drying for two to three days is a pre-requisite for easy grain separation during threshing, but this may not be achieved due to weather conditions. In Nepal, the advent of the winter season coincides with harvesting and so having adequate number of sunny days is an issue.
4. Low air during the winnowing increases the labour requirement to as much as 3 times of the labour requirement when there is good air.
5. Threshing on roads leads to grain damage and loss. Threshing and drying on a mud floor is less efficient than on the cement floor and access to cemented threshing yards is limited in the project sites.
6. Small stones, dirt and other varieties of finger millet get mixed with the grains during threshing and drying operation.

Storage of grains and seeds of finger millet

The study revealed that farmers across the sites sundry the grains as well as seeds before storage. Various structures are used for storage of grains and seeds. Usually closed structures are used for seeds. While gunny bags or nylon woven sacs are most commonly used in present days in many of the sites, the majority of the farmers in Nepal store finger millet in a bamboo structure known as *Bhakari* (Table 5). In Anchetty, an underground storage system by name *Kalanjiam* (see picture 4) was used earlier. It is made of wooden planks and it was told that grains stored in *Kalanjiam* will be in good condition even after 10 years. In Semiliguda the grains are stored above the stove in a bamboo structure to avoid moisture during rainy days. This structure is called locally as *Turjhulla* (see picture 5). In Dumriguda grains are stored in the attic (see picture 6). In Bero storage containers made of paddy straw, woven into a basket was used earlier, it was called as *Poval chatka*, and this practice is no longer observed. Plastic bags are made into a big storage container by tying it together with sticks and this is called as *Chatka*. The storage period varied across the sites ranging from one year to a maximum of 5 years for grains and one year for seeds. It is observed by farmers from Nepal site that longer stored finger millet has poor taste.

Insect attack is not a serious problem; hence no special treatment is followed for storing the grains in most of the sites. But in Sri Lanka DDT powder is used to control insects by all the interviewed farmers. Some farmers also use *neem* and *tulsi* to repel insects. In Anchetty too chemical balls are used to keep out insect pest. Rodent damage is reported in Anchetty, Dumriguda, Sri Lanka and Nepal, and rodenticides or traps are used to address this issue.

Picture 4: Picture of *Kalanjiam,* Anchetty **Picture 5: Picture of *Turjhulla,* Semiliguda**

Picture 6: Grains stored in attic, Dumriguda

Table-5: Storage methods for finger millet grains and seeds in project sites

Project sites	Storage structures	Storage period	Remarks
Nepal site	*Bhakari*, clay pots, plastic drums, bamboo baskets, tins	1 ½ years for grains 11 months for seeds	Closed structures for seeds
Anchetty	Gunny bags, mud sall, clay pots, *dombai, kalanjiam*	Grains-Upto 3 years Seeds- 1 year	Structures varied depending on the quantity in earlier days
Semiliguda	Plastic bags, earthen pots	Grains and seeds 1 year	*Turjhulla* during rainy season
Dumriguda	Gunny bags, earthen pots, bamboo baskets, sacs	Grains-2-3 years Seeds – 1 year	
Bero	Gunny bags, plastic bags, *chatka*	Grains upto 5 years Seeds 1 year	*Poval chatka*- a traditional practice
Jawadhu Hills	Gunny bags	Grains upto 2 years, seeds upto 1 year	*Dombai* – a traditional practice
Thanamalwila	Poly sacs, SS utensils, tins, plastic bins, clay pots	Grains and seeds 1 year	Chemicals, neem leaves, tulsi leaves used for seed storage

Processing of finger millet

Grains need to be dried and cleaned to remove thin husk and small stone particles before processing. This type of cleaning manually is a tedious and more time consuming job, which earlier was done by the women. Now, cleaning machines – aspirator and destoner- are available for this purpose (see picture 7). But among the seven sites, it is available only in Anchetty along with flour mill. In some other sites, it is available as part of a rice and other grains processing unit. Flour is the only processed finger millet product made for home consumption. Traditionally grains were hand processed into flour using a stone grinder (see picture 8), called differently in local languages in different sites (*Janto* - Nepal*, Pathar jota* - Semiliguda*, Chakki* - Bero*, Kurakkan stone* – Sri Lanka, *Ariyakkal* - Anchetty). Presently grains are processed in flour mills which are usually accessible within a radius of 5 kilometers distance (see picture 9). In Nepal earlier water powered grinding mills were available; but now electricity based grinding mills are in use. There is a difference in opinion across the sites regarding the comparison of taste between flour made of grinding stone and flour made from the mill. While Semiliguda and Bero farmers expressed reduction in taste of flour made from mill over that of grinding stone, and farmers from Nepal felt the reverse. The difference can be explained by the difference in parameters observed by the communities involved. An interesting observation made by Nepal team is that when grinding was done at home, a tedious job, only women were involved and now both men and women are involved in grinding finger millet in the mills.

Picture 7: Destoner, Anchetty

Picture 8: Stone Grinder

Picture 9: Flour mill, Anchetty

Box 1: Finger millet grains, processed at a time by Sri Lankan Families
In Sri Lankan site it was attempted to understand the amount of finger millet grains, processed at a time by the families in the project villages. The study revealed that the majority of the families process three to eight Kg at a time. This kind of observation helps in doing adaptive research on identifying suitable grinding mills specific to each site.

Amount processed (kg)	< 1	1	2	3-4	5	6	7	8
Percentage farmers	7	8	6	26	23	21	6	3

Leads for action research

1. Weather related issues like heavy rains and cloudy weather during harvest and threshing were observed in many of the sites. Identification of varieties that has ability to perform under these conditions like early maturing variety and variety with non lodging and less shattering characters, and including the same in the participatory varietal selection in the sites can be helpful. The issue of blackening of grains due to continuous rains during harvest is taken up for research under the project for understanding the pathogen involved and for finding ways to address this issue.
2. The labour requirement for harvest and post-harvest operations for finger millet seems to be relatively higher than other cereal crops when it is seen in the back ground of low productivity and low value. Given its value as a nutritious crop, labour efficient practices need to be evolved to address this issue. As observed by few partner research organizations appropriate thresher can be a valid research agenda. More exploration across the sites for the exchange of best practices that can increase labour efficiency can be another approach. Pursuing this research agenda can have significant benefits for women, who bear the major burden of post-harvest handling activities.
3. Introduction of small scale aspirators and de-stoners to other sites as in Anchetty has the potential to improve the hygiene and thereby the quality of finger millet flour. Further exploration in this direction is needed to understand the site requirements and need for such an adaptive research.
4. Any research agenda in PHT of finger millet need to be sensitive about the consequences related to gender aspects, as women are the key players in the post-harvest processes.

3.2 Little millet

Post- harvest handling of little millet was studied in three project sites, namely Jawadhu Hills, Semiliguda and Dumriguda. Harvesting period for the short duration varieties is from September end to October, and January for long duration varieties.

Harvesting– The short duration little millet is harvested manually using a sickle to cut the stalks along with panicles. The stalks are spread in rows on the field for sun drying. After 5 days the stalks are bundled and staked near the threshing yard for a period of one month. Long duration varieties are harvested for panicles only. Last year mechanical harvesting of little millet was tried at Jawadhu hills with minor alterations in paddy combine harvester, but the results were not welcomed among farmers. The loss of grains and the straw was considerable. Further, this technology is not suitable for small holdings with undulated land. Continuous rains during harvest were expressed as the main problem with Jawadhu hills and Dumriguda. Sometimes the seeds germinate when they are in the field itself. Grain shedding is very common if there is a delay in harvesting. At Semiliguda the stalk is covered with bamboo structure, called *Dola*, for protection from rain. Harvesting and staking requires about 2 men and 3 women for one acre area.

Picture 10: Harvesting at Jawadhu Hills **Picture 11: Harvested crop lay in field**

Threshing- The bundled stalks are spread in the threshing yard, mud or tar road, and threshed using cattle (see picture 12) or hand pounding with a stick. Winnowing is done using shallow bamboo baskets, called *Muram. Visu muram* (see picture 13 &14) is used for blowing the wind like a hand fan. Again continuous rains are major problems faced by the community. The problems involved are wet threshing yards and difficulty in separating grain from the panicle. Mixing of soil with grains also reduces the quality of the grains. The cleaned grains are sun dried for 1-2 days before storing. The threshing operation requires about 9 labourers, including both men and women. Farmers in Dumriguda dry small quantities in bamboo sheets placed above the cooking fire in kitchen. Poly sheets are used for drying grains when the drying yard is wet.

Picture: 12: Threshing by bullock **Picture 13: *Visu muram* in use**

Picture 14: *Visu muram* – Close up

Storage and processing – At Jawadhu Hills the grains are sold over a period of time based on need for cash and market price. It was observed that the majority of the farmers keep their produce more than a year and there are farmers who have more than 10 years old stock. Plastic bags, sacs, clay pots, bamboo baskets (*Duddi*) are used for storage of grains. *Khersi*, a special type of storage structure made of mud, reinforced with bamboo and covered with Palmyra leaves is used at Semiliguda site. Dehusking of little millet is usually carried out by hand pounding, using either wooden mortar and pestle or wooden dehusker or both. Stone grinder is used for making flour. It was observed by Jawadhu Hills farmers that using wooden dehusker is easier than wooden mortar and pestle. In Dumriguda dehusking is done at once in 10 to 15 days; but in Jawadhu hills the frequency is less. In Dumriguda, they start with hand pounding with pestle and mortar, followed by sun drying, which is followed by dehusking with wooden de-husker. The community perceived that it is a difficult task and the new generation is not interested in doing this difficult task. This difficulty could be one of the important reasons for the fast decline in consumption of little millet. The community also shared that a mill was set up in Jawadhu hills long back. It did not run for long as people did not prefer the taste of the milled little millet rice, and it was said that the rice made out of milled little millet becomes pasty, while the hand pound retains its shape as rice when cooked.

Picture 15: *Khesri*, storage structure

Picture 16: Pestle and mortar

Picture 17: Wooden grinder

Leads for action research

1) Weather related issues like heavy rains and cloudy weather during harvest and threshing were observed in many of the sites for little millet also. Identification of varieties that has ability to perform under these conditions like early maturing variety and variety with non lodging and less shattering characters and including the same in the participatory varietal selection in the sites can be helpful.
2) Pursuing research for improvising existing paddy harvester to suit for little millet harvesting can be one of the research agenda.
3) From the food security perspective, developing / refining a dehulling machine that is appropriate and functional in terms of meeting the requirements at the research site and dissemination of the same is an important research agenda. Care should be taken to develop prototypes that ensure minimum loss of nutrients in the dehusking process. From the gender perspective also this research agenda is an appropriate one.

3.3 Barnyard millet and Kodo millet

Barnyard millet and kodo millet are extensively grown at Peraiyur site. In the case of barnyard millet the panicles are harvested after the crop maturity. About 10-15 women laborers needed to harvest one acre of land. Harvested panicles are transported to the threshing yard as head load or using tractor by the men labourers. The panicles are kept as such in gunny bags for 1-4 days before threshing. Farmers feel that it helps for easy separation of grains.

Kodo millet is harvested by cutting the stalks along with the panicles which are spread in the field for sun drying for 1-2 days. The operation is known locally as *Avial* or *Ambal.* For harvesting one acre 8-12 labourers are required. Transporting is done same as for barnyard millet. Both the millets are threshed using public tar road as threshing yards. Labor required is 3-4 women and 2 men for barnyard millet, while 5-6 women and 2 men for kodo millet. Some farmers also use a tractor and complete the operation within 45-60 minutes.

Selected panicles are threshed separately for seed purpose. For both barnyard and kodo millet rainfall during harvest is considered as a major problem as it results in lodging of plants, shattering of grains and discolouration of grains.

The cleaned grains of barnyard or kodo millet are usually sold at the yard itself by most of the farmers. Other farmers, having storage facility, may store the grains in gunny bags for a maximum period of one month. The seeds are stored in gunny bags without any treatment or castor seed powder may be mixed with barnyard millet seeds to prevent pest infestation. Usually seeds are sun dried 2-3 times during storage period of 9-10 months. In some villages drying is done on new moon day, as the community believes that there will be less pest attack.

Picture 18: Storage in gunny and cloth bags

Picture 19: Earthen storage pot

Picture 20: Grains stored inside earthen pot

Traditionally kodo millet used to be processed in *Thirugai,* a stone grinder specifically converted for the purpose. Farmers believe that kodo millet has seven layers of husk and so the most difficult grain for dehusking. The grinding surface of the stone grinder is made soft by attaching a gunny bag cloth to the lower surface and a strong cotton cloth (locally called *Gada* cloth) to the upper surface of the stone grinder by pasting it with wet clay. Barnyard is traditionally dehusked using pestle and mortar for rice purpose, and dehusked using stone grinded for gruel purpose.

Processing mills are available at the site in Athipatti and M. Kallupatti villages. These are abrasive type emery roller mills, in which emery stones of larger gradient size are embedded on rollers. The above sited mills are multipurpose mills of bigger capacity and suitable for pulses and small millets. Two passes are required for barnyard millet and three for kodo millet. Time taken to process is 1 hour/qtl for barnyard millet while it is 3 hours/qtl for kodo millet. The conversion ratio is 40 to 50 percent for kodo millet and 60 percent for barnyard millet. There is also facility in the same mills to make flour from the processed millet rice. It was informed by the women informants that bran is lost while dehusking in those mills and not so when done manually. The colour of the kodo millet in hand processing would be yellow while that of mills is white. The rice and flour are stored in gunny bags or plastic container or aluminum vessels upto one month.

Kodo millet poisoning is a major issue related to loss of quality of food grains. Further exploration is required to understand the extent of the issue in the site. Research is taken up under the project for understanding the pathogen involved and for finding ways to address kodo poisoning.

Picture 21: Processing of kodo milet

Picture 22: Three hole stone grinder

Picture 23: Stone mortar

3.4 Associated crops of Small millets

The main associated crops of small millets in the sites are horse gram, rice bean, field bean, linseed and niger. However, the farmers in the project sites do grow other minor pulse crops, but in smaller scale. These crops, whether as sole crop or mixed, are harvested by collecting the whole plant or by collecting only the pods. Threshing for separating the grains is usually by hand pounding with stick. After winnowing and cleaning, the grains are sun dried before storing. Since insect pests are serious problems during storage of pulses different storage methods are followed. Clay pots, tins, plastic containers, plastic sacs are the common structures used for storing the grains. Mixing of castor kernel powder, filling top 1/3rd to half portion of earthen pot above the seeds with sand, placing the storage container of pulses at the center of millet grains stored in big structures, sun drying at frequent intervals are some of the procedures followed across the project sites for storing the grains without infestation.

Picture 24: Storage of associated crops on terrace

4. Major constraints in post-harvest handling of small millets and associated crops

During the study it was possible to enlist a number of constraints related to post-harvest handling of the focused crops. A few of them are common across the project sites while others are specific to particular sites.

- Harvesting coinciding with heavy rains and lack of sunny days leading to problems like lodging, shattering of grains, blackening of grains and straw, increased duration of heaping before threshing resulting in deterioration of quality of grain and sometimes germination of seeds in the fields (due to continuous rains).
- Drying for two to three days is a pre-requisite for easy grain separation during threshing, but this may not be achieved due to weather conditions.
- Low air during winnowing increases the labour requirement to as much as 3 times of the labour requirement when there is good air.
- Labour shortage as majority of farmers do harvesting simultaneously. In Bero and Semiliguda, harvesting coincides with the harvesting of paddy and hence it is prioritized over finger millet.
- The Labour requirement for harvesting and threshing operations is high and given the increase in wages, harvesting is becoming a costly activity.
- In Nepal it is observed that trampling by women results in rashes of the feet and beating with stick results in swollen patches on the palm. Further winnowing results in itching and respiratory problems.
- Threshing on roads leads to grain damage and loss. Threshing and drying on a mud floor is less efficient than on the cement floor and access to cemented threshing yards is limited in the project sites.
- Small stones, dirt and other varieties of finger millet get mixed with the grains during threshing and drying operation, thereby leading to loss in quality.
- Rodent damage is a significant problem in some of the sites for small millets and insect pests are a major problem with the associated crops.
- Lack of adequate processing facility for all small millets except finger millet.
- Dehusking is a tedious and time consuming operation undertaken by the women and an important reason for reduction of consumption

5. Leads for research

1. Weather related issues like heavy rains and cloudy weather during harvest and threshing were observed in many of the sites. The research leads are:
    - Identification of varieties that has ability to perform under these conditions like early maturing variety and variety with non-lodging and less shattering characters and including the same in the participatory varietal selection in the sites can be helpful.
    - Research on the issue of blackening of finger millet grains due to continuous rains during harvest for understanding the pathogen involved and for finding ways to address this issue.
    - Research on the issue of kodo millet poisoning for understanding the pathogen involved and for finding ways to address this issue.

2. The labour requirement for harvest and post-harvest operations for finger millet seems to be relatively higher than other cereal crops when it is seen in the back ground of low productivity and low value. Given its value as a nutritious crop, labour efficient practices need to be evolved to address this issue. As observed by few partner research organizations appropriate thresher can be a valid research agenda. More exploration across the sites for the exchange of best practices that can increase labour efficiency can be another approach. Pursuing this research agenda can have significant benefits to women, who bear the major burden of post-harvest handling activities.

3. Introduction of small scale aspirators and de-stoners to other sites as in Anchetty has the potential to improve the hygiene and thereby the quality small millet products. Further exploration in this direction is needed to understand the site requirements and need for such an adaptive research.

4. Any research agenda in PHT of finger millet need to be sensitive about the consequences related to gender aspects, as women are the key players in the post-harvest processes. As women share a major part of the labor requirement, efforts for the introduction of technology that helps in easing their work
5. Sharing of best practices related to storage across the sites can help in managing pest problem with associated crops

Annexure – 2A: Survey of Post –Harvest Technology and Constraints faced by Women

S.No: | | | | | | | | **Interviewed**

by____

Date:____

I. Socio-economic status

1. Name of the Key informant :____

2. Name and address of the ____

head of the family ____

3. Age (yrs) :_____________________________ 4. Sex : Male [ ] Female [ ]

5. Religion and caste :-____________________________ 6. Caste :____

7. Composition of the family : *Adults (>18 years):* Male [ ] Female [ ]
Children and adolescents: Male [ ] Female [ ]

8. Land area cultivated including leased in and shared land in the last year: ______________________ Acres

9. Small millets and associated crops (SMAC) cultivation details last year before this season:

1_S.No.	2_SMAC	3_As main crop or inter crop	Last year area *(in acres)*	
			4_Kharif	5_Rabi
1	Little millet			
2	Finger millet			
3	Horsegram			
4	Niger			

II. Post-harvest Technologies and constraints (The following tables are with reference to the area cultivated for each SMAC last year)

10. Details of Post-harvest drying, staking and transporting to threshing place of last year crops

1_S. No	2_SMAC	3_Describepost-harvest drying, staking and transporting to threshing place in terms of how, when (days after harvest and month) and where they are done?	4_Labour in mandays for each operation		5_Constraints faced	6_Efforts done to address each constraint
			M	F		
1	Little millet					
2	Finger millet					
3	Horsegram					
4	Niger					

Note: M- Male; F- Female

11. Grain/pod/kernel separation details of last year crops

1_S. No	2_SMAC	3_Describe grain/pod/kernel separation method, in terms of the different activities like threshing, winnowing, etc. when (days after harvest, month), how and where they are done?	4_Labour in mandays for each operation		5_Constraints faced	6_Efforts done to address each constraint
			M	F		
1						
2						
3						
4						

Note: M- Male; F- Female

12. Details of drying of grains/kernals/pods of last year crops

1_S .No	2_SMAC	3_Drying method followed	4_When drying done?	5_Duration of drying (days)	6_Done by *(code)*	7_ Constraints faced	8_Efforts done to address each constraint
1							
2							
3							
4							
					7: Done by *Female-1* *Male--- 2* *Transgender -3* *Both----4*		

13. Storage of grains/kernals/pods of last year crops

1_S .No	2_SMAC	3_Form of storage	4_Type of storage container	5_Duration of storage (days)	6_Done by *(code)*	7_ Infestations faced	8_Details of efforts done to address infestation, both preventive and after infestation
1							
2							
3							
4							
					7: Done by *Female-1* *Male--- 2* *Transgender -3* *Both----4*		

14. Storage of seeds of last year crops

1_S .No	2_SMAC	3_Form of storage	4_Type of storage container	5_Duration of storage (days)	6_Done by *(code)*	7_ Infestations faced	8_Details of efforts done to address infestation, both preventive and after infestation
1							
2							
3							
4							
					7: Done by *Female-1* *Male--- 2* *Transgender -3* *Both----4*		

15. Details of processing of SMAC

1_S. No.	2_SMAC	3_Processed product *(code)*	4_Description of the processing method including type of machinery used, different steps, quantity per batch, conversion ratio, frequency, storage of processed item, etc.	5_Place *(code)*	6_Price/fees	7_Time taken (hrs)	8_Done by *(code)*
		3: Processed product *Rice-----------1* *Grit-----------2* *Flour---------3* *Others, specify------99*		**5: Place** *Home-------1* *Own village-2* *Nearby village-------3* *Others, specify-----99*			**7: Done by** *Female---1* *Male----- 2* *Transgender -3* *Both-------4*

16. Mention three important processing constraints faced by you related to each SMAC (in the last 2-3 years)

1_S. No.	2_SMAC		3_Processing related constraints	4_Efforts done to address each constraint
1		1		
		2		
		3		
2		1		
		2		
		3		
3		1		
		2		
		3		
4		1		
		2		
		3		

17. Post-harvest losses: (Include both quantity and quality loss like spoilage of grains eg: poisoning of kodo millet)

18. Any other details of importance:

Annexure – 2B: Result of pair-wise ranking among male participants in Kaskikot VDC, Kaski, Nepal

Problems	Double harvesting(a)	Mental pressure for softening of heads (b)	Threshing is difficult ©	Dehulling is difficult (d)	Winnnowing is difficult (e)	More labor requirement (f)	More involvement of women (g)	Problem of rodents (h)	More duration of drying (i)
Double Harvesting (a)	x	a	c	a	E	a	g	a	a
Mental pressure for softening of heads (b)		x	c	d	E	f	g	b	i
Threshing is difficult ©			x	c	E	c	c	c	c
Dehulling is also difficult (d)				x	E	d	d	d	d
Winnowing is difficult (e)					X	f	e	e	e
More laborlabor requirement (f)						x	f	f	i
More involvement of women (g)							X	g	i
Problem of rodents (h)								x	i
More duration of drying (i)									X
Total score	5	1	7	5	7	4	3	0	4
Rank	III	VIII	II	IV	I	VI	VII	IX	V

Result of pair-wise ranking among female participants in Kaskikot VDC, Kaski, Nepal

	Double harvesting(a)	**Mental pressure for softening of heads(b)**	**Threshing is difficult ©**	**Dehulling is difficult (d)**	**Winnnowing is difficult (e)**	**More labor requirement (f)**	**More involvement of women (g)**	**Problem of rodents (h)**	**More duration of drying (i)**
Double Harvesting (a)	x	b	c	D	E	f	a	a	a
Mental pressure for Softening of heads (b)		x	c	D	E	f	g	h	i
Threshing is difficult ©			x	C	C	f	c	c	c
Dehulling is also difficult (d)				x	E	f	d	d	i
Winnowing is difficult (e)					X	f	e	e	i
More laborlabor requirement (f)						x	f	f	f
More involvement of women (g)							x	g	g
Problem of rodents (h)								x	i
More duration of drying (i)									x
Total score	3	1	7	4	5	8	3	1	4
Rank	VI	IX	II	V	III	I	VII	VIII	IV